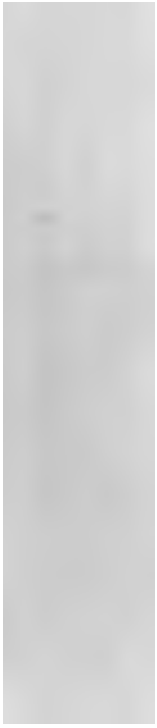
Rudiments of Geology

SHARP.



RUDIMENTS

OF

GEOLOGY.

BY

SAMUEL SHARP, F.S.A., F.G.S.

PART I.

INTRODUCTORY AND PHYSICAL.

PART II.

STRATIGRAPHICAL AND PALÆONTOLOGICAL.

SECOND EDITION.

"Μέγα βιβλίον μέγα κακόν"

LONDON:
EDWARD STANFORD, 55, CHARING CROSS.
1876.

TO

JOHN EVANS, ESQ.,

VICE-PRESIDENT OF THE ROYAL SOCIETY,

PRESIDENT OF THE GEOLOGICAL SOCIETY,

VICE-PRESIDENT OF THE SOCIETY OF ANTIQUARIES,

PRESIDENT OF THE NUMISMATIC SOCIETY,

ETC. ETC.;

WHO TO MANY OTHER ACTS OF KINDNESS TO THE AUTHOR

HAS ADDED HIS ACCEPTANCE OF THIS

DEDICATION.

May, 1875.

PREFATORY NOTES TO SECOND EDITION.

In preparing this Edition, I have made a thorough revision, and such corrections and alterations as I deemed necessary or desirable.

I have taken advantage of the opportunity to re-write, with greater particularity, but still with a view to conciseness, the Sections in the Second Part treating of—the *Laurentian*, the *Cambrian*, the *Devonian* and *Old Red Sandstone*, and the *Carboniferous* Systems.

I have also added, in the First Part, several Sections, upon—*Landslips, Valleys, Mountains and Hills, Volcanoes, Aerolites, Changes of Climate over large Areas*, etc.; and, in the Second Part (page 185), a *Table of the Succession of Life upon the Earth.*

I have brought down my information as nearly to the present time as possible; and I hope I have succeeded in rendering the *Rudiments of Geology*, in this its Second Phase, more valuable as an *initiatory book for learners*, and more useful as a "*handy book*" *of reference* to those who already know something of the Science.

My warmest thanks are due to the following Gentlemen, who have done me the honour to revise respective portions of my Work:—Dr. CARPENTER, F.R.S., Mr. JOHN EVANS, F.R.S., Dr. HICKS, F.G.S., Professor HULL, F.R.S., Mr. J. W. JUDD, F.G.S., Professor JOHN MORRIS, F.G.S., and Mr. WOODWARD, F.R.S.

I beg to thank also—Mr. CARRUTHERS, F.R.S., Professor DUNCAN, F.R.S., and other Geologists, who have kindly supplied me with information; and especially Mr. ETHERIDGE, F.R.S., who, in addition to aid in the shape of revision, has liberally furnished me with the drawings for my Figures, Nos. 1, 4, 5, 6, 7, and 9.

SAMUEL SHARP.

Dallington Hall, Northampton,
March, 1876.

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CORRIGENDA.

Page 21, foot-note. Add *Part II.* to the end of the line.

„ 36, foot-note (*), line 3. After "varying expansion," add, *and contraction.*

„ 54, last line but one of text. After "Tremadoc," add, *and equivalent rocks at.*

„ 54, line 3 of par. 2 of "NOTE." For the present words of the text, read—"and the more recent *inquiries of the former* [Professor Ramsay], and the persistent and well-directed labours of Dr. Hicks," etc.

„ 69, last line of par. *c*. For "Euryptidæ"—read, *Eurypteridæ.*

„ 78, 80, par. *f*''''''. "Arborescent Mosses": this is a mistake—the *Lycopodiaceæ* and *Club-mosses* are *not true Mosses*, but only *Moss-like.*

„ 80, par. *g*, line 3. For "Mosses"—read, *Club-mosses.*

„ 92, line 3. Insert *the* before "Upper Lias Clay."

„ 107, par. *b*. The *Archæopteryx*.—On account of certain indications, Mr. Evans suggested that this was a *dentigerous* Bird [See par. *e*, p. 131, and par. *c*'''' and foot-note, pp. 142-3]; and this view is probably correct.

RUDIMENTS OF GEOLOGY.

PART I.

INTRODUCTORY AND PHYSICAL.

1. The derivation and meaning of the word "Geology."

It is derived from two Greek words, "*ge*," the Earth, and "*logos*," a discourse; and it means *the study of the Earth.*

2. The difference between the sciences of Astronomy and Geology.

a. Astronomy is the study of the stars and of *the Earth as a stellar object*—as an integral *part* of a stellar system.

b. Geology is the study of the *Earth as a whole*, as being complete in itself.

3. The *broad* meaning of the term "Geology" is the study of the Earth and of *all* that belongs to the Earth.

The *scientific and applied* meaning of the term is the study of all the *materials* of which the Earth is composed.

4. Geology has been divided into:—

a. Stratigraphical Geology—derived from the Latin word "*stratum*," that which is out-spread or spread over, and the Greek word "*grapho*," I write.

b. Palæontological Geology—from the Greek words "*palaios*," old, "*onta*," existing things (or beings), and "*logos*," a discourse.

c. Physical Geology—from the Greek "*physis*," nature.

a'. Stratigraphical Geology is the study of the layers, or beds, or *strata*, in which the materials of the Earth's surface are found to be arranged.

b'. Palæontological Geology is the study of the remains of *animals* and *plants* which the strata of the Earth are found to contain; and these remains are called "*fossils*"—from the Latin word "*fossilis*," that which is dug out of the earth.

c'. Physical Geology is the study of the *natural causes* an *origin*—of the different strata and their contents, of the existing arrangement of land and sea, and of the present surface contour (*i. e.* the occurrence of hill and dale, mountains and plains, rivers and lakes and seas); and, in some phases, it is nearly allied to Physical Geography.

5. The chief objects of Geological inquiry are:—

a. The materials, nature, fossil contents (both animal and vegetable), order, origin, and relative ages, of the strata making up the so-called "*crust*" of the Earth.

b. The solid materials of the Earth are estimated to extend downwards from the surface to a depth of about 34 miles;* below which depth, it has been considered that the Earth's matter is in a molten or more or less fluid condition, owing to the great heat of the interior of the Earth.† The Earth is

* *Vide* Lyell's *Principles of Geology*, edit. 1872, vol. ii., p. 206.

† This conclusion may be subject to some modification. Professor Hopkins, of Cambridge, upon a mathematical process of reasoning, estimated the thickness of the crust of the Earth, variously, at 400, 800, and 1,000 miles, and concluded that there existed a central solid nucleus; but his views have not been fully accepted by more recent physicists, although entertained to a certain extent by Sir Wm. Thompson.

roughly 8,000 miles in diameter; and, as the solid materials have only so small a thickness comparatively, they have been termed the "crust" of the Earth.

c. The term "crust" of the Earth has also been used as indicating that solid portion of the Earth's mass which (by natural processes to be hereafter described) have been brought within the reach of Man's observation.

6. All substances with which we are familiar in daily life are derived directly or indirectly from stratified or unstratified rocks or beds included in the objects of the Geologist's study; such as:—

a. Directly—Stone of various kinds for building, clay for bricks or pottery, slate for roofs, etc., marble (for statuary, pillars, chimney-pieces, and hearth-slabs), coal, limestone, sand, gravel, granite and other stone for roads, ores of the various metals (iron, copper, tin, zinc, lead, gold, silver, etc.), all precious stones, rock salt, and many other things.

b. Indirectly—Spring and river waters, manufactured salt, gas for lighting, glass, porcelain, earthenware, paint and many drugs, all metals, the soil upon which the vegetable world exists, etc., etc.

c. Still more indirectly—Plants, animals, our food, and Man himself.

7. The *useful*, *moral*, and *religious*, results of the pursuit of Geological science.

a. The *useful* results of Geological science are found in the knowledge it affords:—

a'. Of the nature of the materials of the Earth's strata, of the localities and depths from the surface at which they are found, of the facilities which may exist for their being

obtained, and of the applicability of their products to the purposes of life. Examples—the substances enumerated in the last Section, namely, water from springs and wells, coal, stone, lime, clay, salt, all metals, etc.

a''. Of the nature of soils and substrata for the purposes of cultivation.

a'''. Of the stability or instability of underlying beds in the question of obtaining firm foundations for buildings.

b. The *moral* results of the pursuit of Geology are traceable, not only in an increase of knowledge and enlightenment, but in the fact that, in the practical application of that knowledge, the personal comfort and consequent refinement of society is promoted, and thus civilization is advanced.

c. The *religious* results of Geology are to be recognized in an appreciation of such wonderful works of Creation as Geology alone has been able to open up to our knowledge—works of Creation, both animal and vegetable, of such varied, strange, and multitudinous forms, as to exceed in interest and to out-number the different kinds of animals and plants existing upon the Earth at the present time; serving to display the all-skilful, all-wise, and all-benevolent creative works of the Deity upon the Earth, extending back through ages of progressive changes in the physical conditions of the Earth's surface, so prolonged as to be only paralleled by the profound distances in space and incalculable periods of time which Astronomy discloses.

8. The various materials of the Earth within the scope of our observation, which apparently have been accidentally distributed in different localities and at various depths, have been placed as found by the necessary operation of natural

laws; which laws have operated through all time and all over the Earth, and are even now operating.

9. The materials (or rocks) composing the Earth's crust may be classed into two principal Divisions—the *Igneous* and the *Aqueous*.

a. The Igneous are those which have been formed by the action of great internal heat—such as granite, probably the foundation of all rocks, and the original source whence the materials of many have been derived; and such as lava, basalt, and other substances, which have been thrown up by deep-seated internal forces or ejected by volcanoes.*

b. The Aqueous are those which have been formed by the agency of water (at the bottoms of rivers, lakes, estuaries, and seas), and are for the most part sedimentary.

b'. Limestone Rocks are of Aqueous origin, but are chiefly composed of matter derived originally from animal life. Among these, are a class of rocks which are not sedimentary—Coralline Rocks, which have been built up in the ocean in the forms of coral reefs and coral islands, by the so-called "coral insect": which is not an insect at all, however, but a *Zoophyte*—a name compounded of the Greek words "*zoon*," an animal, and "*phyton*," a plant; it having formerly been mistakenly supposed that this class of forms presented a connecting link between animals and plants.

b''. Some Aqueous rocks have had a *chemical* origin—such as those formed by the precipitation of carbonate of lime.† The rocks last described as having been derived from animal structure, have also had indirectly a chemical origin, in the lime in solution absorbed by animals during life.

* See forward, Sec. 32, *Volcanoes*, pp. 33–35.

† See forward, Section 14, par. *a'''*, page 11, *Sub-aerial Denudation*; and Section 28, par. *c*, page 26, *Springs*.

c. There are other rocks, constituting a kind of Intermediate Division, and partaking to a certain degree of the nature of each of the former Divisions: these are rocks which have been originally formed by Aqueous action, and entirely altered by contact with heated Igneous rocks, or water at high temperature, deep under ground. These are called "*metamorphic*" rocks—from the Greek words "*meta*," implying change, and "*morphe*," form—indicating that their form has been changed.*

d. There is another class of rocks, such as peat, lignite, and coal,† which do not bear so large a proportion to the whole as either of the foregoing; which may be termed Semi-aqueous, having been formed, for the most part, in wide-spread marshes, in warm swamps or "savannahs," and in "deltas"; and which have been derived from vegetable growth.

e. There are also material objects which differ from all other substances upon the Earth, in the peculiarity that they are not of terrestrial origin, but have fallen through the atmosphere upon the Earth. They are called "*aerolites*," or air-stones,‡ and are generally very metallic in their composition.

10. The labours of Geologists are devoted more generally to the *Aqueous* Division—

a. As presenting the greatest aggregate thickness of beds accessible to observation.

* "*Meta-morphóomai* (*meta, morphe*)—to be transformed, to be transfigured."—*Liddell and Scott.*

† "Sand, mud, clay, peat, and coal, are rocks" (*i. e.* in a *Geological sense*).—Geikie's *Science Primer*, "*Geology*," Art. 45, p. 19.

‡ Greek—"*aer*," air, and "*lithos*," a stone.—For a more particular description of Aerolites, see forward, Section 37, page 36.

b. As exhibiting the greatest variety in the nature of the materials of which its beds are composed.

c. As its beds are almost exclusively those which contain the remains of organic forms called fossils.

d. As pointing to the most varied physical causes of the formation of strata, and of Geological changes.

And to this Division, therefore, will our attention be mainly directed.

11. All sedimentary strata or beds, however different in material composition (whether consisting of clay, shale, slate, limestone, chalk, sand, sandstone, conglomerate, or gravel), have been arranged by the operation of natural forces, in a certain order of *vertical sequence.**

a. For instance—the order of succession (or "*vertical sequence*") of beds in the neighbourhood of Northampton† (which are all of sedimentary origin) is as follows:—

Vertical Sequence of Beds in the Neighbourhood of Northampton.

	Duston and Kingsthorpe.	*Northampton.*	*Great Houghton and Blisworth.*
1	. . . . .	. . . . .	Clay.
2	Limestone.	. . . . .	Limestone.
3	Brick Clay.	. . . . .	Clay.
4	Sand and Sandstone.	Sand and Sandstone.	Sand.
5	Red Building Stone.	Red Building Stone.	Red Stone.
6	Ironstone.	Ironstone.	Ironstone.
7	Brick Clay (Lias).	Brick Clay (Lias).	Brick Clay (Lias).

b. In other parts of this country and of the world, whatever stratified beds occur, the same kind of order of succession (or vertical sequence) is everywhere found to prevail.

* See forward, Section 19, page 18.

† In lieu of illustrations presented in these Sections, the sequence of beds in any locality may be adopted.

12. The Geological terms "*stratum*" and "*bed*" mean nearly the same thing. A stratum is a horizontal layer of material, of whatever kind, which does not admit of re-division, and varies in thickness from a few inches to a greater or lesser number of feet.

13. A "*Formation*" may consist of one "stratum" or of a group of a few or many "strata." The question of what constitutes a "*Formation*" is determined by a variety of considerations, such as—identity of material (sometimes), uniformity of fossil contents, identity of position in a vertical sequence, or the fact that the area can be defined over which a distinguishable stratum or group of strata occurs, etc.

Thus:—

a. The Clay and Limestone, Nos. 1 and 2 of the Northampton * series, are both of marine origin, and contain the same kind of fossils; but, one being clay and the other limestone, and in vertical succession, they are distinct Formations: the limestone Formation, be it noted, consisting of several strata, varying in thickness, hardness, and mineral character.

b. The Clay, No. 3, is a distinct Formation; for its contents tell us that it was formed in the estuary of a large river.

c. The Sand and Sandstone, No. 4, is a distinct Formation; for, although also of estuarine origin, there comes between it and No. 3, in the Northern parts of the county, a thick bed of marine limestone, indicating that a long period of time had intervened between the formation of the one and of the other, and that the estuaries in which they were deposited were not the same.

* See Note (†) on page 7.

d. The Red Building-stone and the Ironstone, Nos. 5 and 6, constitute one Formation, as the difference occurs only locally: in some places, the upper (No. 5) contains more iron than the lower (No. 6), and over a wide district in the Northern parts of the county there is very little iron in either. The area of this Formation is pretty clearly defined —as spreading, from Mid-Oxfordshire, through Northamptonshire, Rutland, Lincolnshire, into Yorkshire, as far North as Whitby. This Formation, therefore, will come under the last-named indication of what constitutes a "Formation."

e. The Brick Clay (Lias), No. 7, being a clay, and containing a very distinct group of fossils, is a definite and very important Formation.

f. It must be borne in mind that a "Formation," however defined, represents a *distinct period in time.*

14. The processes by which Sedimentary strata have been formed "at the bottoms of rivers, lakes, estuaries, and seas." [See *ante*, Section 9, par. *b*, page 5.]

All Sedimentary strata have been formed from the materials of pre-existing rocks, which have been wasted by a process called "*denudation.*"* There are several kinds of "denudation":—

a. "*Sub-aerial*" denudation—from the Latin "*sub*," under, and "*aer*," the air. The effect of frost and snow and rain upon the surface of the Earth is continually to wear away that surface, especially in mountainous regions. Frost shatters or softens the harder materials: snow and rain shower down water upon the surface, causing a general flow from higher to lower levels. During thaw or rain, may be

* From the Latin word "*denudare*," to strip, to bare.

seen small muddy streams pouring down the hilly roads, and depositing a thick sediment at the level bottoms. When there is a flood, the water is always muddy from the material washed from the higher grounds: by and by, the flood subsides, and the water of the river clears, because the mud which discoloured it has been either deposited on the meadows or carried down by the stream to be deposited elsewhere. Thus, the material of higher levels is ever being conveyed by rills into rivulets, by rivulets into brooks and streams, by these into rivers, and by rivers into "valleys, lakes, estuaries, and seas."

a'. Hence, great mud banks and other accumulations are formed at the mouths of rivers—such as abound in the great Lincolnshire Wash, into which flow the Ouse, the Nene, the Welland, rivers all rising in Northamptonshire, and the Witham which rises in Rutland: hence, also, have we large accumulations of sediment in the estuaries of the Thames, the Severn, the Humber, the Southampton and other rivers, in England, the Shannon in Ireland, in the Firths in Scotland, and in the respective outlets into the sea of other drainage systems of streams, as before described.

a''. So, by the melting of the ice and snow of the higher Alps in spring, small streams are converted into torrents, and an immense amount of material is carried downwards: the lake of Geneva is being rapidly shallowed, and its area at its Eastern extremity diminished, by the deposits of mud brought down by the Upper Rhone.

The chief rivers of the Americas, the Ganges and Indus of India, and other great rivers wheresoever situated, each annually carries to the ocean many millions of tons of denuded matter. The whole flat country of Egypt has been formed by deposits of the Nile, brought by its Eastern

branches from Abyssinia, and by its main course from more Southerly districts, reaching nearly to the Equator.

a'''. Another fertile form of Sub-aerial Denudation occurs in the wasting of rocks containing soluble matter—such as lime, which, as gypsum (sulphate of lime), and as limestone of many Formations and chalk (both carbonate of lime), is more or less dissolved by the action of water charged with carbonic acid: * by this means, carbonate of lime, in a state of chemical solution, is taken up, and by all large rivers is conveyed in amazing quantities to the sea; where it is in small part deposited by precipitation, and in greater part absorbed by the many forms of marine life into the structure of which lime largely enters. Thus, lime, in the dead remains of animal organisms, is deposited in the sea-bottoms, or by the living creature is built up into coral reefs, which again become limestone; † and so the circle is completed.

a''''. The whole land-surface of the Earth, by these various processes of sub-aerial denudation, is constantly contributing materials to the ever-accumulating deposits at the bottom of the ocean. The mean rate of this denudation in its mechanical forms has been approximately estimated at one foot in 6,000 years; ‡ but to this must be added the important amount of waste by chemical solution described in the last paragraph, and which has not been included in this calculation.

a'''''. Many valleys, through the meadow flats of which small rivers now flow, have been excavated by those very

* See forward, Section 28, *Springs*, par. *c*, page 26.

† See *ante*, Sec. 9, par. *b''*, page 5.

‡ *Vide* Croll, *Geological Magazine*, 1871, pp. 97–102; also A. Tylor, *ibid.*, 1872, pp. 492–495.

rivers, when of greater volume, and under more favourable conditions, and the abraded materials carried down to the sea.

b. "*Marine*" denudation. The sea is always encroaching upon the land: wherever upon the sea-shore you see a cliff, there you have evidence of marine denudation—a cliff is merely the vertical section of land from which other land has been cut away by the sea: this process is universally going on. A cliff is gradually hollowed out and undermined at its base, by the force of the waves; the face and upper portion of the cliff become fissured and loosened by frost and rain, and at length topple down upon the shore below; this loose material * is then carried away by the tides and sea-currents, and is deposited as sediment at the bottom of the ocean. This process of marine denudation has led to many falls of cliffs at Dover and other parts of England—whole estates have gradually disappeared in this way; and in the North of Norfolk, this waste is occurring to such an extent, that it is thought that the present site of the pleasant town of Cromer will in a generation or two become a continuous part of the bottom of the neighbouring sea. The sea-bottom is also sometimes abraded by oceanic currents.

c. "*Glacial*" denudation. This is the waste of the higher peaks of mountains by the disintegrating effects of frost, and of the sides and bottoms of valleys and ravines by the vast accumulations and fields of ice called "glaciers." Glaciers have always a downward grinding motion, and they tear and wear away the rocks with which they come into contact: this very downward motion conveys (both upon the surface of the ice and below it) to the bottoms of the valleys —to the lower ends of the glaciers (which are there con-

* "*Detritus*" it is called, from the Latin "*detritus*," worn.

tinually melting away)—the materials denuded by these two causes; and these materials are there deposited in huge banks, called "*terminal moraines*." *

c'. Hills of considerable height have been thus formed by the ancient glaciers of the Southern and Eastern sides of the Alpine chain: the great "moraine" of Dora Baltea (or Ivrea), on the plains below the mouth of the Val d'Aosta in North Italy, has a circuit of about 60 miles and a height exceeding 1600 feet; † and traces of "moraines" are to be found in the valleys of every mountainous district in which glaciers of important size have at any time occurred.

c''. In the Northern and Southern polar regions of the Earth, the lower ends of mighty glaciers run down into the ocean, are broken off by the action of their own flotation in the sea, and are floated away as "icebergs" (or ice-mountains), laden with masses of rock and other materials from the bottoms and sides of the valleys in which the glaciers have been formed; and these rocks and materials, as the icebergs melt, fall to the bottom of the ocean.

d. The three several forms of denudation described, and the consequent processes of aqueous deposition, now in operation, are the same as, under varying conditions, have produced, during the extended periods of Geological time, all the different kinds of sedimentary rocks.

15. How the various forms of animal and vegetable life (now known as fossils) became enclosed in the sedimentary rocks.

a. The waters of seas, estuaries, lakes, and rivers, abound

* "*Moraine*" is a French word, derived from the Italian "*mora*," a heap of stones.

† *Vide* Ramsay's *Physical Geology of Great Britain*, p. 149; and Lyell's *Antiquity of Man*, 1873, page 35^, fig. 46.

with forms of life, and have done so from remote epochs of Geological time. It has ever been an ordained law of life that death should succeed life, even as the night succeeds the day: it has always been that all living things die.

a'. The ocean bed forms the sepulchre of all things that have lived in the ocean—shells of mollusca, bones and scales of fishes, skeletons of sea mammals and birds, the carapaces and bones of turtles, the hard cases of lobsters, crabs, and other crustacea, star-fishes, the stony frames of zoophytes, and sea-weeds, are ever being imbedded in the continuously accumulating sediment of the sea-bottom; and to these are added a very few (proportionately) land animals and plants, and shells of fresh-water mollusca, brought down by streams.

a''. The deposits in estuaries contain the remains of animal forms which thrive best in the alternation or admixture of salt water and fresh water; and these are commingled with fresh-water remains, brought down by the streams, and with marine remains, brought up by the tides.

a'''. The deposits in lakes and rivers contain only the remains of fresh-water forms of life, with the occasional accidental introduction of land forms of life.

b. It is thus, by a study of the nature of the organic remains (or fossils) which a Formation contains, that Geologists are enabled to determine whefher such Formation had its origin in a marine, or in an estuarine, or in a fresh-water deposit.

16. How it is that strata deposited at the bottom of the ocean, and containing marine fossils, are found at considerable distances from the sea, and at con-

siderable elevations above the sea-level; and that estuarine, lacustrine, and fluviatile strata, in like manner, are found in situations where estuaries, lakes, and rivers, do not now exist.

a. Even from the time when first the Earth obtained a solid crust, every part of its surface has been alternately rising and sinking—parts of its surface are rising at the same time that other parts are becoming depressed; but these upward and downward movements are so slow as to be inappreciable, except by careful observation.

Thus:—

a'. It has been found that for some centuries the Northern districts of Norway and Sweden have been rising, and that Greenland has been sinking, at about the rate of two feet in 100 years.

a''. The Western coasts of Southern Italy are slowly rising. During the last 1,600 years, the ruins of the temple of Jupiter Serapis at Pozzuoli, near Naples, have sunk some 25 feet beneath the water of the Bay, and have risen again to about their previous level—as is indicated by multitudes of holes bored by a small stone-boring sea-bivalve called "*Lithodomus*" * in three standing columns at a height of 23 feet from their bases: so that these columns must have been immersed in the sea to that depth, and have again risen to their present position, by the alternate sinking and rising of the land.†

a'''. In the Southern Pacific Ocean, many of the numerous coral islands are found to be rising, whilst others are sinking.

* Greek—"*lithos*," a stone, and "*domos*," a house.

† Lyell's *Principles of Geology*, edit. 1872, vol. ii., p. 164–179; Phillips "*Vesuvius*," pp. 238–246.

b. The portions of the Earth's surface which are thus rising are called "areas of elevation"; those which are sinking "areas of depression."

b'. Every portion of the Earth's surface has been alternately land and sea; and this, throughout the area of this country, over and over again.

c. Thus, by the combined action of denudation and of the alternating elevation and depression of the Earth's surface in areas, all the sedimentary rocks, as we find them, have been formed and placed; and thus, by the operation of the same processes, are even now accumulating, upon the deep floors of seas, sedimentary beds, which, in some far remote future, may constitute the fossiliferous strata of wide continents of dry land, occupying areas now covered by the profound waters of mighty oceans.

17. Beds having the same mineral character have not always the same Geological origin.

a. For example, there are several kinds of gravel, three kinds of chalk, and many kinds of clay, limestone, sandstone, etc., all of which belong severally to different Formations. Moreover, in tracing out the areas of Formations, it is often found that limestone, in its horizontal extension, passes into sand or sandstone, and these into clay,—or the reverse. These variations in the materials of any one bed are mainly the result of corresponding local variations in the materials of the pre-existing rocks, which, having been wasted by denudation, were re-deposited during the period of the formation of that bed.

b. The mineral character of a bed, therefore, is by itself no indication of the Geological Formation to which that bed belongs.

18. A stratum or bed is to be identified as belonging to any particular Geological Formation by its *fossil contents.*

a. This is a modern discovery. In very ancient times, the occurrence of marine shells and other fossils, sometimes at great heights above the level of the sea, and sometimes at great depths in the Earth, had been observed, and led to various and often very wild speculations; but until nearly the close of the last century, no attempt had been made to associate certain fossils with particular Geological beds, or to establish any systematic classification of Geological strata, either as to area or to vertical sequence.

b. This was at length accomplished by Wm. Smith; who, in consequence, has been styled "The Father of Geology"—because upon this great discovery is chiefly based the present structure of Geological Science; and he is justly considered to rank with the greatest scientific discoverers of this century. He was born of humble parents, at Churchill, in Oxfordshire, in 1769; and he died, in 1839, at Northampton, and was buried in St. Peter's Churchyard in that town.

c. Wm. Smith early in life began to collect fossils, and the slight elementary knowledge he thus acquired led him, when he became a surveyor and an engineer, to examine closely the fossils contained in the different rocks with which the pursuit of his occupation made him acquainted. He found generally that each separate bed contained a separate, a distinct, set or series of fossils; so that he was ultimately enabled to identify by its fossil contents any bed with which he had been previously acquainted, wherever it might be situated, and whatever might be its mineral character.

19. This led Smith to make a further great discovery. I have enumerated the several Geological beds which occur in the neighbourhood of Northampton, and described the order of their "vertical sequence."* Smith, in prosecuting his work as to the identification of beds (or Formations), established the fact, that the relative position in a vertical sequence of beds which could be severally distinguished by their fossil contents, never varied.

a. Supposing he found in some locality five beds (which we will call *a*, *b*, *c*, *d*, *e*) placed one upon another thus— *a* *b* *c* *d* *e* he might find elsewhere *a* lying upon *c* and *b* wanting, or *b* lying upon *e* and *c* and *d* absent, or any one Formation lying upon any other *lower* in the scale; but he never found *c* lying upon *a*, nor *e* upon *b*, nor any Formation overlying another which elsewhere had occurred above it.† This sequential order in the relative vertical position of Formations has been confirmed by all subsequent investigation.

b. Wm. Smith also discovered that, although in a limited district Geological beds may be apparently horizontal (piled up one upon another vertically like the storeys of a house), yet, when examined over a wider expanse of country, they are found to lie in a slanting and overlapping position, "like pieces of bread and butter on a plate,"‡ portions of all in succession coming to the surface.§

* See *ante*, Sec. 11, Table, page 7.

† This statement is subject to modification in cases of extreme distortion or folding of strata; which I have not deemed it necessary to treat of more particularly in this work.—See forward, Sec. 27, par. *c*, and Fig. 6, p. 25.

‡ Professor Geikie—*Scientific Primers, Geology.*

§ This is a result of internal movements in the Earth's crust, described in Section 16, pp. 14–16.

c. This fortunate disposition of Geological beds brings the whole (notwithstanding their immense aggregate thickness) within reach of the examination of Geologists.

20. General deductions which have been drawn from the discoveries of Wm. Smith.

a. That the order of superposition or vertical sequence of sedimentary strata establishes their relative ages—those which are lowest being necessarily the most ancient, and those which are highest the most recent.

b. That their comparative mean thicknesses represent generally the comparative periods of time occupied in their formation.

b'. It is probable that exception must be made in cases of abrupt and deep depressions in underlying surfaces; which depressions (as the consequence of their being depressions) have been filled with irregular rapidity by deposits having thicknesses greatly in excess of the general thicknesses of the Formations to which they may respectively belong. An instance is perhaps offered in the unexpected and unexampled thickness (1,700 feet) of Kimmeridge Clay pierced by the recent Sussex boring.*

c. That the contents of each bed indicate the conditions under which its formation (or deposition) took place.

21. The following great facts, as the results of these deductions, have been established:—

a. That the formation of the "crust" of the Earth occupied many and very extended periods of time.

b. That during those periods, the surface conditions of the Earth, and the nature and forms of its animal inhabitants

* See forward, Pt. II., Sec. 32, *Kimmeridge Clay*.

and of its vegetable growth, underwent very numerous and complete changes.

c. That the several groups of strata form, as it were, museums, in which are preserved the remains of many of the animals which existed and of the plants which flourished during each long period of those strata's formation.

22. Advance made in the Science of Geology since the time of Wm. Smith.

Upon the foundation that he laid, have worked—the French Cuvier, and Buckland, Mantell, De la Beche, Sedgwick, Murchison, Lyell, Phillips, Forbes, Darwin, Ramsay, many other British, and a multitude of Foreign Geologists, in every Quarter of the Globe, and nearly in every country of the World: so that, by their labours, has been upreared the wonderful structure of Geological Science as it now is; comprising—a knowledge of all classes of strata upon the Earth, their chronological order, and, for the most part, the Geographical position and extension of each, its mineral and chemical constituents, and its organic contents. And hence has been obtained an acquaintance with the grand series of physical phenomena by which the elaboration of the Earth's surface into its present perfect adaptation for all purposes of human civilized existence has been effected.

23. *Geological Terms* used in reference to peculiar dispositions of Geological beds.

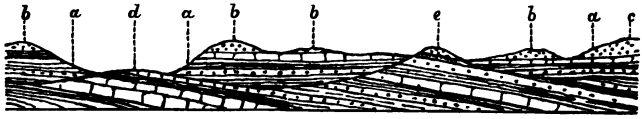
a. When a bed is inclined, (and in this position it frequently passes under other beds), it is said to "*dip.*" When a bed rises above another bed, and thus, from between two beds, comes to the surface, it is said to "*crop out.*" The direction of the "dip" is necessarily directly opposite to

that of the "outcrop." Thus, the same bed "dips" in one direction, and "crops out" in the opposite direction.

b. The portion of the bed which thus "crops out" extends in a line at right angles to that of the "dip" and "outcrop," and is called "*the strike*,"—from the German "*streichen*," a word adopted by German Geologists, and meaning "to extend," "to have a certain direction."

c. Sometimes beds become thinner and thinner, until they cease: this is called "*thinning out*."

Fig. 1. *Escarpments—Outliers—Inliers.*



a, a, a. Escarpments. *b, b, b, b.* Outliers of Formation *c*.
d. Inlier—example 1 *e.* Inlier—example 2.

d. An "*escarpment*" is a more or less inclined surface (such as the border of a valley, the side of a hill or mountain, or the rise from a lowland to a table-land), upon which "crop out" one or more Formations occurring in its locality.*

e. An "*outlier*" is a portion separated from and lying *beyond* the general mass or spread of a Formation, just as an island is separated from the mainland. It is generally a fragment left by denudation; but occasionally "outliers" have been originally formed as isolated masses, as in the case of coral-reefs, numerous modern examples of which are presented in the Coral Islands of the Pacific Ocean.

f. "*Inliers*" are portions of an underlying Formation which have been exposed by denudation; whether in the excavation of valleys (*d*), or in consequence of an undulation

* See also forward, *General Remarks* (*a*), following Sec. 33, and Fig. 9.

in, or other irregularity of, the surface of the Formation exposed (*e*).*

g. A "*section*" is either—an actual vertical surface (such as may be exposed in a cliff, quarry, railway-cutting, well, shaft, or boring), exhibiting *in situ* the sequence and thicknesses of strata; or a written or diagrammatic representation of such a sequence, in any locality or across any particular line of country, constructed from a knowledge of the succession and general thicknesses of strata in either instance. Such a "section" of a locality is sometimes called a "gathered section."†

24. A *Geological Map* shows, by means of different colours assigned severally to different Geological Formations, where each Formation occurs as the surface bed; and it thus indicates the general directions of the "dip" and "outcrop" and line of "strike" of every group of Formations occurring within the area of the map.

a. The peculiarities indicated by the Geological Map of this country are, that—the oldest Formations are situated in the West and North-West; the later Formations in the South-East and South; and those of intermediate age between, belting the country from the South-West to the North-East.

b. It may thus be seen that the general direction of the "dip" is to the South-East, of the "outcrop" to the North-West, and of the lines of "strike" from the South-West to the North-East.

25. *Anticlinal and Synclinal Axes and Curves.*—A modification of the causes which have produced the inclination of

* "Outliers" are always *newer*, and "inliers" are always *older*, than the Formations which surround them.

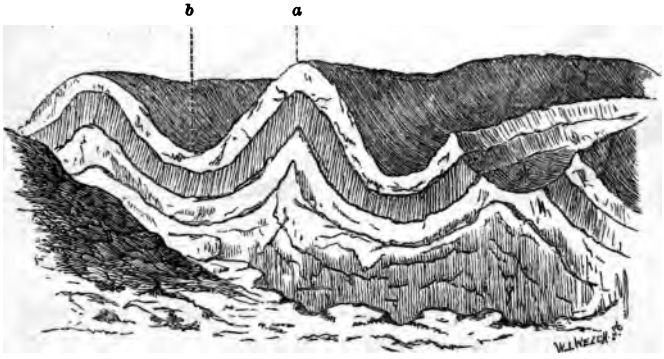
† See *ante*, "Vertical sequence of beds in the neighbourhood of Northampton," page 7.

strata has in many cases resulted in the *curvature of strata*; which have been forced by lateral pressure sometimes into immense ridges and furrows, culminating occasionally in the elevation of ranges of mountains.

a. The summit line of such a ridge is called the "*anticlinal*" line or axis—from the Greek words "*anti*," opposite, and "*clino*," I incline; meaning that the inclination (or "dip") on the two sides of the ridge is in opposite directions.

b. The line of furrow is called the "*synclinal*" line or axis—from the Greek words "*syn*," together, and "*clino*"; meaning that the inclines are towards each other.

Fig. 2. *Anticlinal and Synclinal Axes and Curves.*



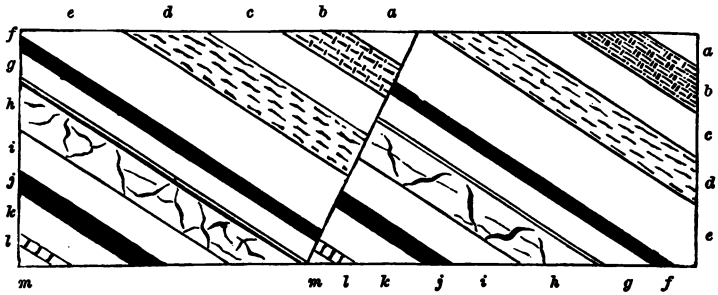
a. Anticlinal Axis. *b.* Synclinal Axis.

* Anticlinal Valley—see forward, Sec. 30, *a*, page 28.

26. *Faults.*—Certain displacements are frequent in Geological strata, which are called "*faults.*" Sometimes the rate of elevation or depression [see Section 16] is not uniform over a given area—portions of that area may rise or sink more rapidly than other portions: other phenomena (such as earthquakes, the shrinkage of underlying beds, etc.) also

produce alterations in level. The result is, vertical or inclined fractures through strata, and an interruption of their continuity: strata are brought into horizontal contact with other strata not normally upon the same level; but which, in regular vertical sequence, occur either above or below them. These dislocations (another name for the same thing) were first called "faults" by workmen in coal-mines, where they frequently occur; because, by them, coal-seams were sometimes brought to an abrupt termination, and the miners were thus "at fault" to find coal.*

Fig. 3. *Diagram of a Fault in Coal Measures.*



The beds *a*, *b*, *c*, *d*, etc., on the one side of the fault, are identical with the beds *a*, *b*, *c*, *d*, etc., on the other side of the fault.

27. *Unconformity.*—Another peculiarity in the position of beds is called "*unconformity.*" This is:—

a. When one group of beds overlies another group of beds at a different angle of inclination.—*Fig.* 4.

* The "faults" described are "simple" faults: there are "faults" of various kinds—"double" faults, "cross" faults, and others of a more or less complicated character.

b. When a group of beds in a horizontal position overlies another group in an inclined position.—*Fig.* 5.

c. When a group of horizontal or inclined beds overlies a distorted group.—*Fig.* 6.

d. This arrangement of beds has been produced, in either case, in this way—The lower groups originally were deposited as horizontal strata; afterwards they were thrown into an inclined position, or distorted, by internal movements of the Earth's crust;* and, having been more or less wasted by denudation, the superincumbent beds were deposited upon them by the processes described in Section 14, par. *a*, pp. 9–11.

e. The fact that groups of strata occur unconformably in a vertical sequence, is an evidence that, between the several periods of their formation, intervals of time of greater or less duration had passed, involving frequently a long intervening period of dry-land surface.

f. Geologists, therefore, accept "unconformity" of strata as a very cogent mark of distinction between Formations.

28. *Springs* the result of a certain disposition of beds.

a. Rain is the source of all water obtained upon land.

* See *ante*, Sec. 16, page 14–16; and Sec. 26, page 23—Faults.

Falling upon the surface, its water percolates the soil and the rocks beneath (if they be porous), and descends until it is arrested by a non-porous bed; where it accumulates in the overlying porous bed (which thus acts as a filter and a reservoir), until finding natural vent, it issues forth as *springs*.

b. The atmosphere slightly impregnates rain-water with carbonic acid, which thus charged, on encountering limestone or gypsum, dissolves and takes up a certain amount of lime, and appears in wells and springs as *hard water*.

c. Sometimes rain-water encounters in percolation decaying organic matter, becomes more highly charged with carbonic acid, and takes up a still larger amount of lime. Upon exposure, the acid flies off as carbonic acid gas, and the lime is precipitated as carbonate of lime. Hence *petrifying springs* and the deposit (sometimes as rock masses) of calcareous *tufa* and *travertine* *: hence, also, the icicle-like objects, called "*stalactites*," † pendent from the roofs of caverns, and the irregular accumulations upon cavern floors called "*stalagmites*" ‡; which are composed of carbonate of lime, and have been produced by the continual dropping of water thus holding lime in solution.

29. *Landslips.*—When rocky or porous strata overlie a clay deposit having an inclination or a "dip" towards an escarpment or a cliff, it sometimes happens that from saturation by rain, § the surface of the clay is rendered slippery (especially if a thin layer of sand intervenes), and immense

* From the name of a locality near Rome; where it is abundant.

† From the Greek "*stalakios*," dropping, or trickling, or dripping—"*stalasso*," I drop.

‡ From the Greek "*stalagma*," that which drops.

§ See the last Section—*Springs*.

masses of the overlying beds (often having an area of many acres) slide forward over the clay, and subside upon the shore or down the face of the escarpment.

a'. A notable instance of a great landslip occurred on the coast of Devonshire in 1839, after an unusually wet season. A mass, three-quarters of a mile in length, and of great breadth, moved forwards on to the shore, with considerable subsidence, and became separated from the mainland by a chasm, having "a depth of from 100 to 150 feet, and a breadth exceeding 240 feet." * As might be expected, the sunken area is traversed with crevices in every direction, which renders it rapidly amenable to both sub-aerial and marine denudation.†

a''. A series of landslips were witnessed on the river Amazon some years ago, one of which extended "for a mile or two" along the line of coast;‡ and these phenomena seemed not unfrequent in that region.

a'''. Landslips, produced by like causes, have been observed in all other parts of the world.

b. Earthquakes are also a fertile cause of landslips.

c. Evidences remain of many landslips (the results of both sets of causes) which occurred during Geological periods, frequently in connection with "faults." §

30. *Valleys* have been produced by a variety of causes:—

a. On a large scale, by the curvature of strata producing

* Lyell's *Principles of Geology*, edit. 1872, vol. i., pp. 540–3; where is given a "section" and a pictorial representation of the subsided mass.

† See *ante*, Sec. 14, pars. *a* and *b*, pp. 9–12.

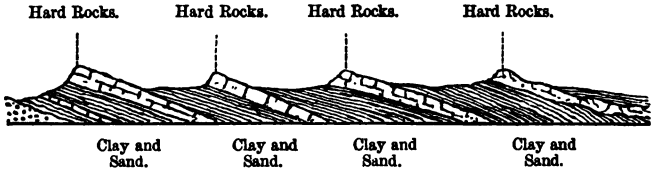
‡ Graphically described in Bates' *Naturalist on the Amazons*, 1863, vol. ii., p. 172.

§ See *ante*, Sec. 26, pp. 23, 24.

anticlinal and *synclinal* ridges and furrows.* The *synclinal* furrows would obviously form valleys; but sometimes curvature has caused rupture of the strata along the line of the *anticlinal* axis, resulting in an elevated valley taking the place of the anticlinal crest.†

b. Valleys and Plains (also on a large scale) are produced by the difference in the *hard* and *soft* character of the most important Formations. Thus—if England were to be traversed from the North-West to the South-East, in crossing the "strike" ‡ of the several Formations, § would be encountered a succession of escarpments and table-lands of hard rocks, alternating with broad valleys and undulating plains of clay, sand, and other soft material; such a configuration of surface being the obvious result of the more rapid action of denuding forces upon the softer than upon the harder groups of strata. ‖

Fig. 7. Alternate Hard and Soft Rocks.



c. In mountainous regions, valleys have been formed, and

* See *ante*, Sec. 25, Fig. 2, page 23.—All such valleys must have been greatly altered from their original conditions by subsequent denudation and deposits.

† See Fig. 2, page 23 (*).

‡ See *ante*, Sec. 23, *b*, page 21.

§ Sec. 24, pars. *a* and *b*, page 22.

‖ See forward, Part II., *General Remarks* (*a*), following Sec. 33.

are being continually deepened, by the excavating action of *ice* or *glaciers*.

d. *Water action*, however, has been by far the most prominent cause of the formation of valleys.* Of the vast amount of water accruing from rainfall,† a certain amount returns to the atmosphere by evaporation, or is absorbed by vegetable growth and ultimately restored to the atmosphere by this means: but the greater portion finds its way into the sea, either by drainage from the surface, or through the medium of springs; and the slow but continuous and prolonged attrition of the running water of rills, brooks, and rivers, (varied by the occurrence of flushes and floods, and aided by frost and other atmospheric action,) has produced the majority of the main and tributary valleys through which rivers and their subsidiary streams now flow.‡

d'. An admirable illustration of the cutting power of running water under certain circumstances, is exhibited in the *Falls of Niagara*, and in the deep and precipitous ravine which intervenes between the Falls and Queenstown. This ravine is seven miles in length, has a depth of from 200 to 300 feet, and a breadth varying from 200 to 400 yards. It is evident that the water of the river Niagara once fell over the cliff-like heights of Queenstown, that by its action the existing channel was gradually excavated, and that thus the Falls have receded from their original to their present

* Valleys excavated by ice have the form of a broad U; those cut by "rain or rivers" that of a V.—Bonney, *Quart. Journ. Geol. Soc.*, vol. xxx., p. 480.

† *Vide Geological Mag.*, 1875, p. 192. During the last three months of 1872, an average of 1,100 tons (246,400 gallons) of water fell on each of the 37,000,000 acres of England and Wales.—Calculated from the Registrar-General's Annual Return.

‡ See *ante*, Sec. 14, *a*, page 9—*Sub-aerial Denudation*.

position. That action is still going on, and the recession of the Falls in the same direction is continuing.

The rate of excavation has varied doubtless according to the varying hardness of the rock cut through; but Sir Chas. Lyell concluded that it might approximately be assumed to be one foot in a year. At this rate, a period of about 35,000 years would be required for the formation of the existing ravine.

Certain fluviatile deposits upon the summits of the cliffs bounding the ravine, mark the former course of the river before the existence of the Falls. These contain various shells of fresh-water mollusca, of species which are now living in the river Niagara above the Falls—proving the identity of the modern fauna with that of the former very remote period.*

d''. The courses of streams and rivers must have been determined by *initiatory areas of depression*, more or less slight; but the causes of these areas of depression are for the most part as yet only conjectured.

e. In some instances, valleys peculiarly situated have not been originally excavated from the surface; but have been produced by the falling-in of the roofs of lines of *caverns*, formed by "long ages of underground action of water," the sides and slopes of the beds having been afterwards modified by the usual surface action of aqueous and atmospheric agencies.†

f. More frequently, but still only occasionally, valleys take wholly or in part the direction of *faults*, or "of lines of

* *Vide* Lyell's *Principles of Geology*, edit. 1872, vol. i., pp. 354–358; where is given a bird's-eye view of the Falls, channel, and surrounding country.

† Professor Phillips—Meeting of British Association at Bath, 1864; *Reports of Brit. Ass.*, 1864, pp. 63, 64.

weakness occasioned by joints having relation to faults."* It may be observed that corresponding strata on opposite sides of river valleys sometimes occur at very different levels—a discrepancy oftentimes occasioned by intermediate faulting; such faulting being commonly concealed by overlying alluvial deposits.

g. Valleys, again, are sometimes the simple negative results of the causes which have effected the upheaval of some mountains—the *intervals* between such mountains, when occurring in chains or groups, being valleys.

31. *Mountains and Hills.*—The causes which have produced Valleys are to a great extent the converse of those which have produced Mountains and Hills.

a. As synclinal furrows have formed valleys, so *anticlinal elevations* have constituted hills and mountains.†

b. As valleys have been produced by the broad "outcrop" ‡ of softer between harder Formations,§ so the outcrop of the harder Formations assumes the character of ranges of hills and "downs" sometimes almost of mountains—*e. g.* the various Chalk Downs, and the Oolitic hills of the Cotteswolds, &c. ‖

c. In the carving-out of valleys by *running waters*, high lands have been left, which have been afterwards fashioned by atmospheric influences.

c'. Thus—Groups of mountains are sometimes but the *remnants of elevated table-lands;* which were first divided into irregular sections by deep precipitous ravines or

* Professor Phillips, *ibid.*; see also Kinahan's "*Valleys and their Relations to Fissures, Fractures, and Faults,*" 1875, chap. vii.

† See *ante*, Sec. 25, par. *a*, Fig. 2, page 23; see also, Sec. 30, par. *a*, p. 27.

‡ See *ante*, Sec. 23, par. *b*, page 21.

§ See *ante*, Sec. 30, par. *b*, page 28.

‖ See Fig. 7, page 28; and Part II. Fig. 9; also, *General Remarks* (a), following Sec. 33.

"cañons," cut by running streams: * these ravines, generally, have been widened out into valleys, from the gradual waste of their cliff-like walls by the action of *meteoric* † agencies—rain and frost, sunshine and wind—alternate saturation and expansion, desiccation and exfoliation; and the flat-topped sections, by the same causes, as slowly converted into peaked mountains of varied size and character. ‡

c''. An idea of the great *waste* resulting from the active operation of these universal agencies, may be gathered from the constant fall of fragments from all precipitous mountain sides and cliffs, and from the innumerable blocks and the amount of *débris* with which every mountain pass is strewn.

d. Ranges of mountains occur along and seal in *great lines of fracture* in the solid crust of the Earth; § through which have been extruded fused granite and other cognate materials: these, in the form of solidified masses, bear up upon their sides inclined or contorted sedimentary strata originally horizontal, and form a core to, or sometimes (having broken through all) the apex of, each mountain mass. ||

e. Many mountains (and these frequently isolated) are the results of direct *volcanic eruptions*—accumulations of various substances thrown up through vertical vents or "craters." ¶ These are of two classes:—

* For example, the "Cañons" of the Colorado river in California described in the *Intellectual Observer*, vol. iv., p. 309; see also, *ante*, page 29, *Falls of Niagara*.

† "Meteoric"—a word scientifically applied to all phenomena of the *weather*.

‡ See Table-land in Spain, admirably figured in Geikie's *Science Primer of Geology*, page 119.

§ See *ante*, Sec. 5, par. *b*, page 2.

|| See *ante*, Fig. 5 (*), page 25.

¶ From the Gk. "*krater*," a cup; on account of the cup-like form which they assume.

e'. Those which consist wholly of piled up *ejected* materials—lava (sometimes *injected*), pumice, scoriæ, "ashes," &c.; such as the still active Vesuvius * and the long dormant and greatly denuded Volcano of Mull.†

e''. Those which are partly composed of sedimentary strata, between the planes of which fused volcanic matter has been *intruded*, and upon which ejected materials have been heaped. The Puy Chopine in the Auvergne ‡ and Arthur's Seat at Edinburgh (from the latter of which all volcanic energy has long since disappeared) § are examples of the latter kind.

f. Mountains which have originated in igneous causes are subjected to the same waste from *meteoric action* as those which have had an aqueous origin; which waste, as to degree and resulting contours, varies according to the varying nature of the materials acted upon, and the irregular intensity of such action.

32. *Volcanoes*.—There is some diversity in the conclusions of those who have directed their attention to the subject of the sources of volcanic energy and of the initiatory *modus operandi* of the forces evolved.

a. There can be little doubt that these are primarily to be attributed to the *expansive force of steam*. ‖

a'. The upward and downward and other movements in the Earth's crust (as already described ¶), the action of Earthquakes, and the process of shrinkage, have irregularly fractured the hard rocks of that crust, and caused them to be

* *Vide* "*Vesuvius*," by Professor Phillips, 1869.

† Judd—*Quart. Journ. Geol. Soc.*, vol. xxx., p. 220.

‡ Scrope—*Extinct Volcanoes of Central France*, p. 73.

§ Judd—*Quart. Journ. Geol. Soc.*, vol. xxxi., p. 131.

‖ Scrope—"*Volcanos*," pp. 37–44; Phillips—"*Vesuvius*," p. 260; Mallet.

¶ See *ante*, Secs. 16 and 26, pp. 15 and 23.

traversed by *fissures*, varying in importance, and more or less vertical.

a''. By means of such fissures, *water* penetrates to considerable depths in the crust of the Earth; where, being subjected to the influence of great heat, it is converted into *steam*, which acting with immense pressure upon fused and other subterraneous materials, mixes with and forces such materials upwards through cavernous fissures, producing all the surface phenomena of volcanoes with which we are acquainted.*

a'''. This view, to a certain extent is confirmed by the comparative proximity of existing volcanoes to oceans or inland seas.

b. It is an unsettled question whether the condition of fusion of lava, &c., is attributable to the intrinsic or primitive heat of the Earth;† or, whether, after having acquired solidity from the gradual cooling of the Earth's mass, the materials composing that lava have again been fused by heat, developed by the crushing and friction of rocks under pressure, such pressure being produced by shrinkage resulting from a continuance of the cooling process.‡

c. It has been found by experiment in deep borings and mines that, below the first 100 feet, the temperature of the Earth increases one degree Fahrenheit for every 60 or 65 feet of descent (subject to variations from local causes); §

* Phillips—"*Vesuvius*," pp. 250, 262, 263.

† Lyell's *Principles of Geology*, edit. 1872, vol. i., p. 578; Phillips, "*Vesuvius*," p. 324.

‡ *Vide* Mallet's *Theory of Volcanic Energy*, *Phil. Trans.*, 1873, Sec. 67; and Paper in *Quart. Journ. Geol. Soc.*, 1875, vol. xxxi., pp. 511 *et seq.*

§ Lyell's *Principles of Geology*, edit. 1872, vol. ii., p. 206; Phillips, "*Vesuvius*," p. 328.

and there is every reason to conclude that temperature continues to increase in nearly the same ratio below the lowest point at which any observations have been taken, and to great depths.

c'. At this ratio, would be reached—at a depth of from 20 to 22 miles, a temperature of 2,000 degrees, sufficient to fuse if solid all such volcanic products as are extruded in a fused state;* and at a depth of something less than 34 miles, a temperature of 3,000 degrees, "a heat sufficient to fuse almost every known substance." †

d. The rocks formed by the solidification of fused materials injected or ejected by volcanic forces have been grouped into two divisions—those which contain from 60 to 80 per cent. of *silica*, and which are called "*acid*" or "*trachytic*" ‡ rocks; and those which contain only from 45 to 55 per cent. of silica, mixed with lime, potash, magnesia, and other *alkaline* substances, and which are called "*basic*" or "*basaltic*" rocks.

33. *Earthquakes*—which are frequently premonitory of volcanic eruptions, are in some way connected with volcanic activity, and are probably produced by the shocks occasioned by the explosive expansion into steam of water intensely heated when suddenly liberated from a state of great pressure.§

34. Some physicists consider that the forces which effect the slow elevation or depression of the Earth's surface,‖ are

* Phillips—"*Vesuvius*," pp. 260, 262.

† Lyell's *Principles*, 1872, vol. ii., p. 206.

‡ From the Greek "*trachys*," rough, rugged; on account of the roughness of their fractured surface.

§ Scrope—"*Volcanos*," p. 39; Phillips—"*Vesuvius*," p. 260.

‖ See *ante*, Sec. 16, pp. 15, 16.

cognate with those which produce volcanic paroxysms: but there is scarcely sufficient evidence to connect positively the causes of these two diverse groups of phenomena.*

35. Rock Fissures are frequently filled with fused materials which have been injected from below by volcanic pressure. These, upon cooling, have become solid, and in this state are generally harder than the rocks between which they have been interposed; and, consequently, upon the weathering of the latter upon the faces of escarpments or cliffs, they stand out in relief as walls or "*dykes*."

36. Fissures, also, are sometimes filled by the gradual incrustation of their walls from the crystallization of materials extracted from the adjacent rocks by the infiltration of water; hence, have been produced "*veins*," of various character, sometimes *metallic*.

37. *Aerolites*.†—Innumerable fragmentary bodies circulate about the Sun in inter-planetary space (and possibly about the Earth also), of which several groups and streams are known.

a. Multitudes of these bodies pass into our atmosphere; and these, from the heat generated by the friction and pressure of their great velocity through the air, acquire a state of incandescence or combustion, and appear as *meteors*. Some ultimately fall to the Earth; are thence called "*aerolites*," and constitute the objects referred to.

* *Vide* Lyell's *Principles of Geology*, vol. ii., pp. 234–7; where the causes of elevation and depression are chiefly assigned to the varying expansion, from extreme variations of temperature, of deep-lying and immensely thick portions of the Earth's substance.

† See *ante*, Sec. 9, *e*, page 6.

b. Often, while still in flight, from the expansion caused by the generation by heat of gases within themselves, they explode, and fall in showers of small fragments and dust.

c. Aerolites vary greatly in size; some weighing only parts of an ounce, and others many tons. They are irregular in form, and sometimes stony but frequently very *metallic* in their composition; the minerals which they contain being often such as to suggest the idea of an *igneous* origin.

d. It may be thought that the fall of Aerolites is of rare occurrence, and that their aggregate mass is of small amount: but, if those which have been recorded* (a very small proportion, doubtless, of those which have fallen) be reckoned up, it will be found that they represent a very important whole; and, for aught we know, they may have contributed to the store-house of the Earth some substances which otherwise it would not have possessed.†

38. *Changes of Climate over large Areas.*—It will be shown hereafter that, during prolonged Geological periods, remotely separated in time, there prevailed in extreme Arctic regions a climate nearly analogous to that of the warmer portions of the Temperate Zones of the Earth in the present day;‡ and that, at a later Geological period, also of long duration, conditions of cold, such as are now confined to the Arctic and Antarctic areas, prevailed, certainly

* A voluminous and minutely descriptive Catalogue of such Aerolites as are known to have fallen in modern times, by Dr. Flight, F.G.S., of the British Museum, was published serially in the *Geological Magazine*, throughout the year 1875.

† *Vide* Phipson's *Meteors, Aerolites, and Falling Stars*, 1867.

‡ See forward, Part II., Sections—14, *Old Red Sandstone;* 17, *i.*, *Coal Measures;* and 46, *c.*, *Lower Miocene.*

throughout the Northern Hemisphere as far South as the Latitude of the Pyrenees.*

Phenomena so strikingly anomalous as compared with the present climatic conditions of the several regions and areas referred to, have naturally led to many speculations as to their causes.

a It has been suggested that the direction of the Earth's Polar axis, in relation to *the Earth itself*, has not been constant; that, consequently, the Polar areas have not always been identical with the Arctic and Antarctic areas of the present time; and that the changes known to have taken place in the positions on the Earth's surface of regions of cold and of temperate climate respectively, have been the result of Axial variation.

a'. The *form* of the Earth militates against such a theory—"it is flat at the Poles and bulges at the Equator"; the Equatorial diameter exceeding the Polar diameter by 26 miles and a half.

a''. Such a form could only have been produced by its rotation *about its present axis* before its crust had acquired rigidity. This being so, the *direction* of the Polar axis (or *axis of rotation*) was then, is now, *and must always have been*, at right angles to the plane of the present Equator,—as the excessive tangential force resultant from the excess of bulk of the Equatorial belt under rotation, would prevent any prolonged divergence of that direction.

b. The Earth in its orbit is nearest to the Sun during the Winter, and at its greatest distance from the Sun during the Summer, of the Northern Hemisphere. The opposite is the case with the Southern Hemisphere—during its Winter the Earth is most distant from, and during its

* See forward, Pt. II., Sec. 53, *The Glacial Period.*

Summer it is nearest to, the Sun; so that the Winter of the Southern Hemisphere is colder and its Summer hotter than those of the Northern Hemisphere respectively.

b'. There is a slight but continuous change in the direction *as to the Sun* of the Earth's Polar axis, resulting in what is called the "precession of the Equinoxes": the effect of this at some future time will be, that the climatal conditions of the two Hemispheres will be reversed—because, during the Winter of the Northern Hemisphere, the Earth will be furthest from, and during Summer nearest to, the Sun; whilst in the Winter of the Southern Hemisphere, the Earth will be nearest to the Sun, and during Summer most distant from it.

b''. This alternation, with long intervals (25,800 years), has occurred in the past over and over again; and it has been thought that in these changes might be found the solution sought.

b'''. It has been suggested also, that a known alternate increase and diminution in the *excentricity of the Earth's orbit* would, by a very similar effect, account for these variations of climate; as the distance of the Earth from the Sun would vary in accordance with such orbital changes.

b''''. No doubt, both sets of causes (whether in separate or combined action) would influence greatly and diversely the climatal conditions of different portions of the Earth's surface; but it is held that they would be inadequate to effect the extreme variations described.

b'''''. If either hypothesis were fact, *periodicity* must have marked the consequent phenomena; as to which, there is no conclusive evidence.

c. Geographical conditions greatly affect climate, whether over small or extended areas. The Gulf-stream affords a

case in point, as modifying the climate of the British Islands and the West of Europe, upon the shores of which it impinges: the current from the North which flows by Newfoundland and the Eastern coasts of North America, operates in the opposite direction; for, from the numerous ice bergs which it transports, it deteriorates the climate of the regions brought under its influence.

c'. Great as the climatal effects of such exceptional circumstances certainly are, yet, even in conjunction with other known causes having the same tendency, it is improbable that any conditions of the same class, consistent with known natural laws, would be sufficient to effect the results to be accounted for.

d. Another suggestion has been hazarded—that, as the Sun and Solar System move together in space towards a point in the Constellation Hercules, at the rate of about 154 millions of miles per annum, our System (in this "*proper motion*," as it is called) may have encountered warmer and colder regions, as the case might be; and that thus these anomalous phenomena of excessive warmth and of excessive glaciation may have been produced. This, however, would have equally affected the whole Solar System and the Sun itself—as to which there is no evidence.

e. A satisfactory solution of the problem remains a *desideratum*.

TABLE OF CLASSIFICATION OF GEOLOGICAL FORMATIONS,

WITH APPROXIMATE MAXIMUM THICKNESSES.

STRATIGRAPHICAL DIVISION. First Order.	Second Order—*into Systems.*	Third Order—*into Groups.*	Maximum Thicknesses in Feet. 3rd Order.	2nd Order.	1st Order.	Life Periods.
Quaternary or Post-Tertiary.	Recent					
	Post-Pliocene—	Post-Glacial	100			
		Glacial *	280	450	450	
		Pre-Glacial *	70			
	Pliocene [a]—	Newer †	2,000			
		Older ‡	550	2,550		Cainozoic, or Newer Life. From the Greek "kainos," new, and "zoe," life.
Primary.	Devonian [f] and Old Red Sandstone—	Devonian (Upper, Middle, and Lower)				
		Old Red Sandstone (Upper, Middle, and Lower)		18,000		Palæozoic, or Old Life. From the Greek "palaios," old, and "zoe," life.

[f] British Beds, 770 feet; Foreign Nummulitic Limestone, "several thousand feet."—*See p. 145.*

Canada; the former of which are 35,000 French feet (37,000 English feet), and the latter 50,000 French feet (53,000 English feet) in thickness.—*See forward, page 48.*

PART II.

STRATIGRAPHICAL AND PALÆONTOLOGICAL.

1. Systematic Classification of the whole Series of Geological Formations.

Tables of all have been compiled. The appended *Table* shows the whole number of Formations as classed under Three Orders of Division:—

a. Under the First Order, they are classed (commencing with the lowest and oldest beds) as—

A. The "Lower Primary" and "Upper Primary."

B. The "Secondary."

C. The "Tertiary."

D. The "Quaternary" or "Post-Tertiary."

b. Under the Second Order of Division, they are separated into Fifteen *Systems*, and Three Series of *Passage Beds*.*

c. These, under the Third Order, are again divided into many Groups; each of which finally comprises few or many distinct Geological Formations.

2. Other Grand Divisions which this Table exhibits.

Besides the Three Orders of Stratigraphical Division, the immense periods of *time* which Stratigraphical Formations indicate have been classed into Three Great Divisions, or Life Periods:—

a. The "*Palæozoic*," or Old-Life,—the lowest and oldest of the three; the Life-forms of which, as a series, are the

* See Table opposite, and forward, Sec. 20—*Rhætic Beds*.

most dissimilar to those now existing. The lowest, and therefore oldest, Formation of this Life-Division may be said to constitute a Sub-Division—the "*Protozoic*," or First-Life.

b. The "*Mesozoic*," or Middle-Life,—later in the succession of time; the Life-forms of which, as a series, more nearly resemble those now existing, although (with the exception of a very few genera and some microscopic organisms) still of entirely distinct kinds.

c. The "*Cainozoic*," or Newer-Life,—the last in the succession of time; the groups of Life-forms of some of the earliest Formations of which contain some forms now existing. The proportionate number of such existing forms increases in every successive group of Formations, until, in the latest, the Life group consists almost wholly of existing forms: the "Cainozoic" Division, therefore, has been made to include the "Recent" or existing Life Period.

A. Primary Strata—Palæozoic Life Period.

3. The Laurentian System.—*The First Trace of Animal Life.*

a. In wide districts in Canada and in the State of New York, North and South of the river St. Lawrence, are vast beds of *metamorphosed* * rock or *Gneiss*, † which extend over an area of at least 200,000 square miles, and have a thickness exceeding 30,000 feet.

b. The Geological position of these beds is determined by the fact that they underlie other beds of great thickness,

* See *ante*, Part I., Sec. 9, *c*, page 6.

† A German miners' name for granite-like rocks, which split in planes of stratification.

which occur in districts about Lake Huron,* and which occupy the place of (excepting that the lowest beds are a little lower than) the Lower Cambrian, the oldest fossiliferous rocks of this country. These lowest American Formations, therefore, must be classed with the oldest sedimentary rocks yet known.

c. They were distinguished by Sir Wm. Logan, late Director of the Geological Survey of Canada, as the "*Laurentian*," from the districts in which they occur, and were divided by him into the *Lower* and *Upper Laurentian.*

4. The *Lower Laurentian* rocks, which have a total thickness of 18,000 feet, have been found to be traversed throughout considerable regions by a series of *limestone* strata, of varying thicknesses ranging up to 1,500 and 2,000 feet.

a. In 1858, Sir Wm. Logan obtained specimens of this limestone, which he thought indicated the presence of *animal* structure †; and in the following year he exhibited these publicly as the earliest known evidence of the existence of animal life.

a'. His conclusions upon this point were confirmed by subsequent microscopic investigations, rigidly carried out by Principal Dawson, of Montreal, and Dr. Carpenter and Professor Rupert Jones ‡ of this country; who, not only satisfactorily determined that these limestones really contain the traces of animal organisms, but further were enabled to describe the *nature* and *structure* of the organisms themselves. §

* Sir Wm. Logan—*Quart. Journ. Geol. Soc.*, 1864, vol. xxi., p. 46.

† See *ante*, Pt. I., Sec. 9, *b'*, page 5.

‡ See able Exposition in *Popular Science Monthly.*

§ For a full account of the Laurentian System of Canada, and for de-

a''. Thus, in the lowest (and therefore the *oldest* *) Formation yet determined, we have probably *the first occurrence of animal existence*, representing the *advent of life upon the Earth!* and in forms significantly referable to the humblest and least organized group of animal life.

b. These most ancient metamorphosed rocks, having been supposed to be utterly devoid of animal remains, were formerly classed as "*Azoic*" (without-life): they may now, perhaps, be fitly termed "*Protozoic*" † (first-life). Principal Dawson suggested the term "*Eozoic*" (of the dawn of life), and has called the fossil itself the "*Eozoon Canadense*" ‡; and this name has been generally adopted.

c. So low a form of life was this first living thing, that it was almost entirely devoid of the structure and functions which we are accustomed to associate with the idea of a living animal.

c'. It belonged to the class *Rhizopoda*, § was a "gigantic" *compound* ‖ member of a group which existed in many subsequent Formations, and is still existing, as of the lowest

tailed descriptions of the peculiar *fossil* which characterizes it, see Articles in *Quart. Journ. Geol. Soc.*, 1864, vol. xxi.—by Sir Wm. Logan, pp. 45–50; Principal Dawson, pp. 51–59; Dr. Carpenter, pp. 59–66; and Dr. Sterry Hunt, pp. 67–71.—See also Dawson's *Dawn of Life*, 1875; and Dr. Carpenter's *The Microscope and its Revelations*, 5th edit., 1875, pp. 556–560.

* See *ante*, Pt. I., Sec. 20, *a*, page 19.

† Greek—"*protos*," first, and "*zoe*," life.

‡ Greek—"*eos*," dawn, "*zoe*," life; "*Canadense*," from Canada.—*Vide Quart. Journ. Geol. Soc.*, vol. xxi., p. 54.

§ Greek—"*Rhiza*," a root, and "*podes*," feet—root-footed; indicating immobility.

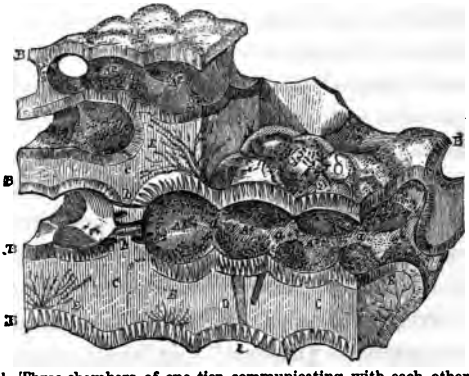
‖ The compound *Rhizopoda* (or *Polythalamia*—Gk., "*polus*," many, and "*thalamos*," a chamber, many-chambered) present the anomaly of many animals being united, as it were, in one—not merely in the association of individuals in one calcareous framework or "skeleton," but in the bodily union of their fleshly substance.

order of animal life-forms—the *Foraminifera*,* and was allied to the later *Nummulite*† and to the living Foraminifera, *Carpenteria*, *Tinoporus*, *Polytrema*, and *Calcarina*.‡

c''. The *Eozoon* had a chambered calcareous skeleton, the enclosing walls of its chambers being of a finely tubulated structure, like that of the shells of the modern *Foraminifera*;

Fig. 8. *Structure of Eozoon Canadense.*§

Portion of the Calcareous Shell (enlarged) as it would appear if the infilling Material were removed.



A^1, A^1, A^1. Three chambers of one tier, communicating with each other directly at *a*, *a*, *a*, and by perforations through separating wall at *b*, *b*.

A^2, A^2. Chambers of higher tier, also communicating at *a*.

B, B, B, B. Enclosing walls of chambers, composed of finely tubulated or "Nummuline" shell-substance.

C, C, C. Homogeneous shell-substance, which constitutes the "intermediate skeleton."

D. Vertical passage between two tiers, occupied by connecting "stolon."

E, E, E, E. "Arborescent" systems of canals.

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* From the Latin "*foramen*," a puncture; these life-forms having certain perforations in their shells, through which the *sarcode* (their fleshly substance) protrudes for some functional purpose.

† See forward, Sec. 43, *Middle Eocene*, pars. *e* and *f*.

‡ Carpenter—*The Microscope and its Revelations*, 1875, p. 556.

§ This Illustration has been taken from the last edition (1875) of *The Microscope and its Revelations*; and I have been enabled to use it by the kind permission of the Author, Dr. Carpenter, F.R.S., and the liberality of the Publishers, Messrs. Churchill, who have lent me the wood block.

and it grew in *tiers*, one over another, separated horizontally by solid intermediate layers or "skeleton" of calcareous or shelly material, into which sometimes penetrated the "arborescent" ramifications of minute canal systems: the chambers were generally continuous, but occasionally united only by minute horizontal perforations in separating walls; the tiers, also, were connected here and there by vertical passages.

c'''. The substance of the *Eozoon* was probably little more than animated gelatinous matter, or "*sarcode*,"* possessing scarcely definite organization; and this sarcode filled and was continuous throughout the enclosing chambers, and occupied as "*stolons*" (or branches, or off-shoots) the connecting passages of beth kinds.

c''''. The number of layers formed in vertical succession sometimes exceeded 100; but, as growth went on, the vitality of the organism seems to have become impaired, so that the layers became thinner: at length, towards the top, the arrangement in layers gradually changed into that of rounded chambers irregularly piled up in what Dr. Carpenter has termed "an *acervuline* † manner." At length, growth ceased; but the upper surface probably gave off reproductive germs, which swam away and formed new colonies. Certain minute organic globular bodies have been discovered, which are thought by Dr. Dawson to have been such germs.‡

d. The Eozoon grew in *clusters*, which coalesced, forming large *sessile* § masses; and fresh and fresh masses were superimposed as the tiers and layers successively lost their vitality,

* Gk.—"*sarx*," flesh, and "*eidos*," resemblance; fleshlike—applied to "the glutinous substance which constitutes the vital mass of the '*protozoa*' or lowest forms of animal life."

† Latin—"*Acervus*," a heap.

‡ *Dawn of Life*, 1875, pp. 66, 67, 139.

§ Latin—"*sessilis*," that which sits easily; without a foot-stalk.

the interstices in the dead parts becoming gradually filled with infiltrated calcareous material.

d'. Thus, great Foraminiferal *reefs* were formed (as are existing Coral reefs) by the building up successively by the living animals of layers above and upon the lower and dead layers of preceding generations.

e. In some beds of the Lower Laurentian of Canada, have been found indications of perforations, which Principal Dawson has suggested may possibly be "*burrows of worms*," * but which have not been determined to be really such.

f. But whether or not these appearances are indications of the contemporaneous existence of *Annelida*,† it is not improbable that other low forms of animal life ‡ and *plants* (not to be identified in a fossil state, and perhaps microscopic,) did exist, and furnished food for the Laurentian Rhizopods; which, in this their earliest development, "attained to a magnitude and a complexity unexampled" in such forms in any subsequent period. Indeed, Principal Dawson affirms that, "in order to the existence and growth of those large Rhizopods, the waters must have swarmed with minute animal or vegetable organisms, on which they could subsist." §

g. The conclusion as to the existence of *vegetable growth* during the Laurentian period is borne out by the fact that carbonaceous matter, bearing traces of organic structure,‖ and the mineral *graphite* ¶ (thought to be derived indirectly from vegetable substance), have been found in these beds.

* *Quart. Journ. Geol. Soc.*, 1866, vol. xxii., pp. 608, 609.

† Worms—"*Annelida*," from the Latin "*annellus*," a little ring; the body being made up of a series of rings.

‡ *Vide* Dawson's *Dawn of Life*, 1875, pp. 136–139—presence of *Archæospherinæ*. (ancient spherical animals) in association with *Eozoon*.

§ *Quart. Journ. Geol. Soc.*, 1864, vol. xxi., pp. 57, 58. ‖ *Ibid.*

¶ Sir Wm. Logan—*ibid.*, page 50.

h. Beds in *Bavaria* and *Bohemia* having the immense thickness of "50,000 French feet" (about 53,000 English feet), have been explored and described by Dr. Gümbel of Munich. In beds of this series, probably equivalent to the Lower Laurentian of America, Dr. Gümbel discovered (in 1863) the presence of *Eozoon*, of a type varying somewhat from that of Canada, and which he has consequently called the "*Eozoon Bavaricum*": * he has suggested, however, that these beds may possibly be referable to the period of the Upper Laurentian, or even of the Lower Huronian.†

h'. The *Eozoon* has also been found in *Finland*;‡ and some peculiar forms from Jersey may possibly turn out to be *Eozoon*, as may (perhaps with less likelihood) certain appearances in the Connemara "Marble" in *Ireland.*

h''. The presence of the Lower Laurentian has not yet been detected in Great Britain.

5. The *Upper Laurentian* Series occurs not only in Canada and in the State of New York, but also—in Bohemia and Bavaria, in Sutherland and the Western Islands of Scotland (being identical with the thick metamorphosed beds termed by Sir Roderick Murchison the "*Fundamental Gneiss*"), possibly in the Malvern Hills in England, and in Ireland.

a. Its thickness exceeds 12,000 feet in America,§ and has been estimated to reach "35,000 French feet" (37,000 English feet) in Europe.‖

* *Vide* Murchison—*Quart. Journ. Geol. Soc.*, 1863, vol. xix., p. 357, and *Siluria*, 4th edit., 1867, p. 373.

† *Vide* Dawson's *Dawn of Life*, p. 149.

‡ Professor Pusyrewski—quoted by Murchison in *Siluria*, 1867, Appendix, p. 550.

§ Sir Wm. Logan—*Quart. Journ. Geol. Soc.*, vol. xxi., p. 45.

‖ Dr. Gümbel, quoted by Murchison, *Quart. Journ. Geol. Soc.*, vol. xix., p. 357.

b. No organic remains have with certainty been found in this Series; unless, indeed, *Eozoon Bavaricum*, may be deemed of this age.*

c. The *Eozoon* seems to have originated in, and to have died out during, the period of the Laurentian System; and, as thickness of strata represents approximately an equivalent passage of time, (unless we accept the unlikely suggestion that *life* originated and ceased during this period, remained for long ages extinct, and was re-initiated at an after epoch), we are led to the conclusion that the *Eozoon* may have lived upon the Earth for a period nearly equal to the sum of the vast periods of time represented by the slow sedimentary formation of all the strata comprised in the Primary (from the Cambrian upwards), the Secondary, the Tertiary, and the Post-Tertiary Divisions; or to more than one-third the sum of all the periods represented by aqueous strata.†

[NOTE.—I have gone to exceptional length in the description of Eozoon, because of its exceptional interest, as affording us the earliest glimpse of animal life, and as being probably the most remarkable object (the oldest and perhaps greatest *rock-builder*) of Palæontological study.]

6. The CAMBRIAN System.

In this country, this System (which received its name from Professor Sedgwick, as occurring chiefly in Wales, the ancient Cambria) has been divided into the *Lower* and *Upper Cambrian.*

7. The oldest beds of the *Lower Cambrian* in the *British Isles* are probably certain Slate beds in the Eastern districts of Ireland; nearly contemporaneous with which, are the great Llanberis and Bangor Slates, the Harlech Grits, and Barmouth Sandstones, in North Wales, other thick beds at

* See *ante*, last page.

† *Vide* Sir Wm. Logan—*Quart. Journ. Geol. Soc.*, vol. xxi., p. 46.

St. David's in South Wales, and those of the Longmynd Mountains in Shropshire.

a. Collectively, these beds are termed the "*Longmynd Group*," constitute the Lower Division of the Lower Cambrian, and have an aggregate thickness exceeding 8,000 feet.

b. The Lower Cambrian Series, in the North-Western Highlands of Scotland, immediately overlies the *Fundamental Gneiss* (Upper Laurentian), and has a considerable thickness. At St. David's, it also overlies *pre-Cambrian* Gneissoid rocks; to which it is unconformable.

c. The Higher Division of the Lower Cambrian in this country consists of slate and flag beds occurring in North Wales, and at St. David's in South Wales. They have been called the "*Menevian Group*" (after the ancient name of St. David's); and they have a thickness of 600 feet.

d. At Bray Head, on the coast of Wicklow, in Ireland, opposite to Carnarvon and Anglesey, in the slaty beds before referred to, were discovered, twenty years ago, certain Life-forms (not more organized than the Laurentian *Eozoon*), consisting of two species of a kind of *Hydrozoa*, and which were named "*Oldhamia antiqua*" and "*Oldhamia radiata.*"*

d'. Doubts have latterly been raised as to these being Life-forms at all, and suggestions have been severally offered—that they are of vegetable origin, and again only accidental wrinklings of the thin laminæ of the matrix.

d''. Until the discovery of the *Eozoon*, the *Oldhamia antiqua* and *O. radiata* were considered to be the most ancient

* "*Hydrozoa*" is derived from the Greek "*hydor*," water, and "*zoon*," an animal; "*Oldhamia*" from the name of the late Professor Oldham, the discoverer. "*Antiqua*" and "*radiata*" are Latin words—the former meaning "ancient," and the latter "radiated," from the form of that species.

of all animal organisms; and (supposing them to be animal remains) they seem, as in the case of the *Eozoon*, to have both originated and died out during the period of the Formation in which they are found.

e. There is little doubt that species of minute *sea-worms* lived contemporaneously (or nearly so) with the *Oldhamia*, and it is probable that some forms of *vegetable* growth (as during the Laurentian periods) did also exist.

f. In strata possibly of equal antiquity to the Irish Slates, have been found fossil indications of four small *Annelida* or sea-worms, in the Longmynd an obscure *Crustacean* (?),* and at St. David's minute *Brachiopoda* and *Trilobites* †—constituting the earliest appearance of animals of these classes.

g. In beds little subsequent to these, although until lately deemed to be almost devoid of organic remains, have been found—in North and South Wales, in Shropshire, in Bohemia and other countries in Europe, and in America—successively increasing numbers of *Life-forms*; which still advance in the character of their organization, and in the variety which they assume.

g'. They consist (in this country) of more than 17 distinct genera and 25 species in the *Longmynd Group*; and these numbers increase to 23 genera and 52 species in the *Menevian Group*.‡ These comprise the following genera, which appear for the first time respectively nearly in the order in which they are enumerated; the existence of many having

* *Palæopyge Ramsayi*—by Mr. Salter: Professor Jukes, however, considered that the supposed Crustacean was only an accidental marking.

† See forward, next page.

‡ These numbers, and the succeeding enumeration in the order of the appearance of genera of the Lower and Upper Cambrian Formations, have been chiefly culled from Papers by Dr. Hicks, F.G.S., in *Quart. Journ. Geol. Soc.*, 1871, vol. xxvii., pp. 384–402, and 1875, vol. xxxi., pp. 190–193.

apparently ceased during the period in which they first occur:—

From the Longmynd Group.

Of *Bivalve Mollusca*,*—the lowest order, *Brachiopoda*,† and the simplest genus, *Lingulella*.
A minute bivalve *Crustacean*, of the genus *Entomostraca*. ‡
Sponges, of the genus *Protospongia*.§
Peculiar *Crustaceans*, of the family of *Trilobites*, ‖ five genera.
A straight-shelled Mollusc, of the order *Pteropoda* ¶ and the genus *Theca* (a sheath).
Of *Brachiopoda*, two somewhat advanced genera, *Discina* and *Obolella*.

From the Menevian Group.

An *Echinoderm*,** an obscure example of the family *Cystidæ*,†† of the genus *Protocystites* (the first of the *Cystidæ*).
Of *Brachiopoda*, a much-advanced genus, *Orthis*.
Two new genera of *Entomostraca*.
Trilobites, eight additional genera, some very large.

h. The sandstones of this Series are occasionally ripple-marked, and we have evidence that the sea-shore sand

* Latin—"*molluscus*," soft.

† Greek—"*brachion*," an arm, and "*podes*," feet; an inappropriate name adopted before the structure of the animal was perfectly understood. The valves (or shells) of Brachiopoda are *dorsal* and *ventrical*, in contradistinction to those of Conchiferous bivalves [see forward, Sec. 8, *a*, note (‡), p. 56], which are on the *sides* of the animal, and termed *left* and *right*.

‡ Gk.—"*entomon*," an insect, and "*ostrakon*," a shell; a shelled insect—the group being provided with bivalve shells or carapaces.

§ Gk.—"*protos*," first; the first sponge.

‖ Gk.—"*treis*," three, and "*lobos*," a lobe; indicating its *trilobed* form.—See forward, page 60.

¶ Gk.—"*pteron*," winged, and "*podes*," feet; wing-footed.

** Gk.—"*echinus*," a Sea-urchin, and "*derma*," skin; implying that the organisms have an exterior covering like that of the Sea-urchin. This group is represented by the ordinary Echinus (or Sea-urchin) and Starfish of our shores.

†† Gk.—"*kystis*," a bladder; indicating its shape.

(even in this most remote era) was diurnally left dry by the fall of the tide: these sandstones are often sun-cracked, and sometimes even pitted by rain-drops, so as actually to indicate the direction of the wind at the time the shower fell.

i. The Lower Cambrian Division is most nearly represented in *America* by a series of *metamorphosed* rocks, having a wide spread in regions on the Canadian side of the Lake Huron,* and hence called by Sir Wm. Logan the "*Huronian Group*." These have the immense thickness of 18,000 feet.† The lower portion of the Huronian Series, however, is thought to be lower than the lowest Cambrian beds of this country, and to be intermediate in time between those beds and the Laurentian.

i'. As in the case of the Lower Laurentian, these rocks are traversed by *strata of limestone* (one stratum 300 feet in thickness), which probably are of *animal* origin; but of the nature of the organisms from which such limestone may have been derived, nothing is known.

[NOTE.—Professor Sedgwick was the first to attempt (after laborious explorations in Wales, &c.) to define the vertical limits of the Cambrian System: in like manner, Sir Roderick Murchison (after as assiduous investigations in Wales and Shropshire) was the first to assign similar limits to the Silurian System. Unfortunately, there is not throughout the combined series of these variform beds, a sufficiently well-marked plane of unconformity,‡ or of stratigraphical separation, to determine positively by such an indication the upward range of the lower or the downward range of the

* See *ante*, Pt. II., Sec. 3, *b*, pp. 42, 43.

† Sir Wm. Logan—*Quart. Journ. Geol. Soc.*, 1865, vol. xxi., p. 46.

‡ See *ante*, Pt. I., Sec. 27, pp. 24, 25.

upper of the two Systems; and, consequently, the views of these two great pioneers of British Lower Primary Geology as to the proper point of separation of the lower from the higher System, were not in accord—the Middle and Upper Cambrian of Sedgwick included rocks, many thousand feet in thickness, which were claimed by Murchison as the lower beds of his Silurian System.*

This discrepancy has been the subject of a *vexata questio* for many years; but the former skilled investigations of Professor Ramsay† and Mr. Salter, and the more recent persistent and well-directed labours of Dr. Hicks, have contributed greatly towards a settlement of the difficulty. As the result of these inquiries, (partly for Stratigraphical, but principally for Palæontological reasons,) at an intermediate point in the vertical sequence of Formations, a plane of separation between these two great systems‡ has been proposed, and generally accepted by the Geologists of this country (although not by all, even among the leaders); and this limitation I have adopted in my Text.]

8. The *Upper Cambrian* (defined as above stated) consists, in its lower Division, of beds in North Wales, at St. David's, and in the Malvern districts, called collectively the "*Lingula Flag Group*,"§ and having a thickness exceeding 5,000 feet; and, in its Upper Division, of the lower portion of a series of slates and rocks at Tremadoc and other places in North Wales, at St. David's, in Ramsey Island off the coast of

* See Article by Dr. Hicks, *Quart. Journ. Geol. Soc.*, 1875, vol. xxxi., Table facing p. 192.

† *Vide Geology of North Wales*, Memoirs of Geological Survey.

‡ Dr. Hicks—Article and Table referred to above.

§ From the prominent Formation, the *Lingula Flags*; so called from the abundance of the small Brachiopod, the Lingula.—See forward, p. 55, note (‡).

South Wales, and in Malvern, which have a thickness exceeding 1,000 feet, and are called collectively the "*Tremadoc Group.*"

a. The known fossils of the *Lingula Flag Group* comprise 20 genera and 30 species, and of the *Tremadoc Group* 24 genera and 45 species; the more prominent of which are enumerated in the following lists:—

From the Lingula Flag Group.

Sponges, of the genus *Protospongia.*
Annelida, in the form of burrowing and other *Worms.*
Trilobites, five genera new, and two continued from older beds.
A *Phyllopod*,* a Shrimp-like *Crustacean*, of the genus *Hymenocaris*,† appears and dies out.
Lingula‡ and three other new genera of *Brachiopoda* appear.
The *Pteropod* genus *Theca* is continued from older beds.
The genus *Bellerophon* of a new order *Heteropoda*,§ a floating Mollusc (allied to Pteropoda, but having a whorled shell).

From the Tremadoc Group.

Protospongiæ, which dies out.
A genus (*Dictyonema*‖) of the order *Polyzoa*,¶ now first appears.
A *Crinoid*,** of the genus *Dendrocrinus*,†† both family and genus now first appear.
A *Starfish*, of the genus *Palasterina*,‡‡ family and genus both new.

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* Greek—"*phyllon*," a leaf, "*podes*," feet; leaf-footed.

† Gk.—"*hymen*," a membrane, "*caris*," a Shrimp.

‡ The humble genus *Lingula* lived on through all subsequent Geological periods, and exists in modern seas.

§ Gk.—"*heteros*," different, and "*podes*," feet; differing from Pteropoda.

‖ Gk.—"*dictyon*," network, "*nema*," thread; because of its thread-like reticulated structure.

¶ Gk.—"*polus*," many, and "*zoa*," animals; also sometimes called "*bryozoa*," moss-like animals—because these "minute mollusca live united in masses in a branched and moss-like manner."

** Gk.—"*krinon*," a lily, and "*eidos*," of the form or resemblance; like a lily.

†† Gk.—"*dendron*," a tree; a tree-like Crinoid.

‡‡ Gk.—ancient little star.

Trilobites, two new and five older genera.
Brachiopoda, four genera.
Bivalves of the higher order *Lamellibranchiata* * or *Conchifera* † (which order now first appears), five genera.
Cephalopoda,‡ the highest order of Mollusca, are for the first time represented by one genus, *Orthoceras*. §
Theca and *Bellerophon* are continued.

b. Rocks both of the older and later Cambrian periods occur in *Bohemia* (where they were termed by Barrande "*the Primordial Zone*"), ‖ and in *Sweden*.¶

b'. Beds, 700 feet in thickness, equivalent to the Upper Cambrian of this country, occur in *Canada*, and are called the "*Potsdam Sandstone*": these overlie the Huronian Series.

b''. All these foreign beds have yielded numerous Fossils, which for the most part correspond in genera with those found in the equivalent beds of this country.

9. The SILURIAN System.

a. The term "Silurian" was adopted by Sir Roderick Murchison because the districts in which he first explored this series of strata are nearly identical with the country once possessed by the ancient Celtic people, the *Silures*.

* Latin—"*lamella*," a thin plate, and "*branchiæ*," gills; descriptive of the characteristic respiratory apparatus of this order of Mollusca.

† Greek—"*kogche*," an Oyster, Mussel, or Cockle; Latin—"*concha*," any Molluscous shell: in Conchology, only applied to Bivalves not being Brachiopods. See *ante*, p. 52, note (†).

‡ Gk.—"*cephale*," the head, and "*podes*," feet; head-footed—so called from the arrangement of *tentacles* or arms (used also as feet) about the head. This order of Mollusca is represented in modern seas by the Nautilus, Cuttle-fish, Octopus, &c.

§ Gk.—"*orthos*," straight, and "*keras*," a horn; straight-horned—to distinguish the straight form of this genus from the numerous succeeding curved forms of the class.

‖ *Vide* Article by Murchison, *Quart. Journ. Geol. Soc.*, 1863, vol. xix., pp. 354–364; also, Lyell's *Student's Elements*, 1874, p. 487.

¶ Murchison—*Siluria*, 1867, p. 350; Lyell's *Elements*, p. 488.

b. It is not, however, a very appropriate name; for these districts, consisting only of parts of Wales, Herefordshire, and Shropshire, present a very insignificant area as compared with the vast Geographical range of the Silurian Formations.

b'. They occur in Westmoreland, Cumberland, and adjacent parts of Lancashire and Yorkshire—in Worcestershire, Gloucestershire, and Somersetshire—in Cornwall, in the opposite land of Brittany, and in the neighbouring Channel Islands—in the Isle of Man, and throughout immense tracts in Ireland and in Scotland both North and South.

b''. They have been found, too, in every Quarter of the Globe, and nearly in every part of the World, and are probably the most universally distributed series of any in the great sequence of Geological Formations.*

c. The System in this country has been divided into the *Lower* and *Upper Silurian* Series.

10. The *Lower Silurian* Series (according to the classification now generally adopted) comprises three distinct

* They occur in Norway and Sweden, the Island of Gothland, Finland, and Russia—in Central Germany, the Harz, Saxony, Bohemia, Bavaria, and in the Rhine districts—in Belgium, France, Portugal, and Spain—in Sardinia, North Italy, the Austrian Alps, and Turkey—in the Himalaya range in India, in China, and in Australia—in the American Arctic regions, in Canada and the States (constituting the rocks through which the Niagara channel has been cut)—all through the vast Western portions of both North and South America, including the great ranges of the Rocky Mountains and the Andes—and in North and probably in South Africa.

Their chief development, however, is in the Northern Hemisphere, and North of the 30th degree of Latitude. The Cambrian and Lower Silurian together are thickest on the borders of the Atlantic; thinning out on the European side to the N.E., and on the American side to the N.W. The *faunas* of both series are suggested to have been derived by migration from a point in the South Atlantic.—Hicks, *Quart. Journ. Geol. Soc.*, 1875, vol. xxxi., pp. 552 *et seq.*

Groups, which have been designated respectively as the "*Arenig Group*," the "*Llandeilo Group*," and the "*Bala* or *Caradoc Group*."

a. The *Arenig Group* has been so called from the Arenig Mountains (Cadir Idris, &c.) in Wales: it occurs also in Carnarvonshire and at St. David's, and includes, as its base beds, the Upper Tremadoc Rocks *: to it also belongs the arenaceous quartzose rocks in Shropshire, the "Stiper-Stones."

a'. This Group has a total thickness of 4,000 feet, and its rocks consist of slates (sometimes ferruginous), shales, flags, flaggy sandstones, and grits.

a''. The most remarkable fact in the *Palæontology* of the Arenig and equivalent beds, is the first introduction in great abundance of a peculiar group of Life-forms, in the *Graptolitidæ*,† which belong to, and may be almost said to constitute, the order *Hydrozoa*. The *Graptolites* are of the lowest class of *Zoophytes*, and the question as to whether they were animal or vegetable organisms was for a time in dispute.

Seven genera and 48 species of *Graptolites* are known as occurring in the Lower Arenig rocks; and these numbers increase in higher beds, so that the System has yielded altogether some 37 genera and sub-genera,‡ and more than 100 species. Their presence is almost confined to the Lower Silurian Division; as in the Upper Silurian very few genera occur, and before the close of the period they disappear. They are not confined to this country, but have been found at points as remote as Canada and Australia.

a'''. In this Group also, appears for the first time a curved form of *Cephalopoda*, *Cyrtoceras*,§ foreshadowing the

* See *ante*, pp. 54, 55.

† Greek—"*graptos*," written, and "*lithos*," a stone; a stone-pen—from a fancied resemblance which some of its forms bear to a pen-feather.

‡ Hopkinson and Lapworth, *Quart. Journ. Geol. Soc.*, 1875, vol. xxxi., pp. 633–635.

§ Gk.—"*kyrtos*," curved, "*keras*," a horn.

numerous *whorled* forms, such as Nautilus, Ammonites, &c.; also a new order of Mollusca, *Gasteropoda*,* univalve shells, so universally abundant in the present day, whether as marine, fresh-water, or land genera.

a''''. Nearly every family of Life-forms which characterized the Cambrian System is represented in the Arenig Group, with variations in and increased numbers of genera.

b. The *Llandeilo Group* takes its name from the town of Llandeilo in Carmarthenshire; but its Formations occur also in Radnorshire and Pembrokeshire.

b'. Its beds consist, in the lowest portion, of a great thickness of black shales with interbedded *ejected* † volcanic ashes and other materials; in the middle portion, of limestone beds, and black ferruginous slates with calcareous bands; and in the upper, of slates and flags with *injected* or *intruded* ‡ volcanic materials. The total thickness (which has been greatly enhanced by the interposition of volcanic materials) reaches 10,000 feet.

b''. The *fauna* partakes very much of the character of that of the last Group, but is marked by the great increase in the numbers both of genera and of species. *Corals* now first occur, but only sparingly.

c. The *Bala* or *Caradoc Group*. The former name is taken from the town of Bala in North Wales. The Group includes important strata called the "Caradoc Sandstone," from the Caradoc mountain range in Shropshire, and other strata at Snowdon, Llandeilo, and in East Pembrokeshire.

c'. The beds of this Group comprise—shales, flags, sandstones, and grits, with calcareous bands, intercalated with volcanic ash, &c. These last not only cause the thickness

* Greek—"*gaster*," the belly, and "*podes*," feet; belly-footed—Mollusca, such as snails, &c., which have arranged along the belly, feet or a muscular disc, adapted for creeping.

† See *ante*, Secs. 31, 32, pp. 33–35. ‡ Ibid.

of beds in different localities to vary considerably, but add greatly to the total thickness of the whole Group, which reaches 12,000 feet.

c''. The *fauna* of this Group was more abundant than that of the last, and it exhibits important alterations.

c'''. The *Trilobites* seem to have attained to their meridian during this period: no less than 23 genera, numbering more than 110 species, having been obtained from this Group alone.

Trilobites first appeared (as already stated) in the Cambrian System, became the most characteristic Life-forms of the Silurian period, began to decline during the latter portion of that period, dwindled during the Devonian, and died out during the Carboniferous period. They were, perhaps, the scavengers of those ancient seas,* which they dominated until the advent of fishes.

Trilobites had a horny or calcareous covering,† a shield-like head, a body of jointed rings or segments, sometimes extending to the posterior extremity—the latter, however, having been frequently covered with a shield like that of the head: the eyes in many species were prominent, and consisted of many facets like the eyes of the Dragonfly; sometimes the eyes were small, and sometimes altogether absent. Some species of *Trilobites* rolled themselves into a ball (probably when alarmed); and the largest attained to lengths often exceeding a foot.

Trilobites have no analogue in the existing fauna, although some naturalists have traced a resemblance to them in the King Crab. "They are now generally believed to be most

* *Vide* Salter, *Monograph on the Trilobites*, *Pal. Soc.*, p. 9.

† Supposed to be intermediate in structure between the horny shells of Lingula and the calcareous shells of recent Crayfish or Crabs.—Hicks, *Quart. Journ. Geol. Soc.* 1875, vol. xxxi., p. 375.

nearly related to the order to which the Wood-lice belong"*: the rolling up into a ball seems to accord with this view.

11. The *Upper Silurian* Series, also consists of three Groups—the "*Llandovery*," the "*Wenlock*," and the "*Ludlow*" Group; each of which has been again variously sub-divided.

a. The rocks of the *Lower Llandovery* division (from the town of that name in South Wales) consist of hard slaty strata and beds of conglomerate, having a thickness of from 600 to 1,000 feet. The known fossils of these beds number 128 species, of which 93 have been found in older rocks.

a'. The *Upper Llandovery* division is represented mainly by the May Hill Sandstone. It ranges from a point West of the Longmynds in Shropshire, in a South-West direction, to the coast of Pembrokeshire. It is 800 feet thick.

a''. Of the *fossils* of this division, about 230 species are known; of which, 83 species are common to lower beds.

b. The *Wenlock Group* (which has a thickness exceeding 4,000 feet) consists of the Woolhope Limestone and the Denbighshire Grits, and the Wenlock Shales and the Wenlock and Dudley Limestones.

b'. The Woolhope Limestone (only locally developed) and the Denbighshire Grits have a great thickness, and with the succeeding Wenlock Shales form "mountain ranges through North and South Wales: these are generally marked by the great sterility of the soil where they occur."† They contain fossils of Upper Silurian types, including a very few characteristic forms. Near Terannon, they overlie the so-called "Terannon Shales," which are about 1,000 feet thick, and are nearly barren of organic remains.

b''. The Wenlock Shales proper have a thickness of more

* Bonney—*Manual of Geology*, p. 88.

† *Vide* Lyell's *Student's Elements*, 1874, pp. 465, 466.

than 1,000 feet; and the overlying Wenlock and Dudley Limestones are about 150 feet thick.

b'''. The Wenlock Limestone forms a continuous ridge in Shropshire, ranging for 20 miles from N.E. to S.W., "due to the solidity of that rock, and to the softness of the shales above and below it." *

b''''. The Wenlock and Dudley Limestones are remarkable for numerous Crinoids and for the abundance of Corals which enrich their fauna. Of Corals, 53 species are known.

c. The *Ludlow Group* has been divided into the Lower and Upper.

c'. The *Lower* consists chiefly of a dark grey argillaceous shale with calcareous concretions, and is nearly 1,000 feet in thickness: it includes also an overlying sub-crystalline and argillaceous Limestone; which takes its name from Aymestry in Herefordshire, and is 150 feet thick.

c''. *Commencement of Vertebrate Life.*—In the Lower Ludlow Division is the first occurrence of a Life-form of the order *Vertebrata* † (the higher of the two grand Divisions under which all forms of animal life have been classed)—a fact most important, as representing great advance in animal organization. This was a *Fish*, of the genus *Pteraspis* ‡: it was allied to the living Sturgeon, and was by no means of a low grade of fishes; which would seem to imply that other fishes had preceded it, although none older have yet been discovered. This fish (and many other succeeding early fishes) exhibited the characteristic of being covered with a shelly armour, comparable to the carapaces of Crustaceans, although they had little or no affinity with Crustaceans. This fish had also a peculiar form of tail, called the "*hetero-*

* Lyell—*Student's Elements*, p. 462; see also *ante*, Pt. I., Sec. 30, *b*, p. 28.

† Latin—"*vertebra*," a joint; animals having a vertebral column or backbone.

‡ Greek—"*pteron*," a wing, and "*aspis*," a shield; wing-shield.

cercal," * because the two lobes were dissimilar, the vertebral column extending into and to the end of the upper lobe. This peculiarity was characteristic of all fishes living during the whole of the Palæozoic Life-Period; but it only occurs in the present day in the Bony Pike (*Lepidosteus*) and allied fishes of the American lakes and rivers and of the African rivers, in the Sturgeons, and in the Shark tribe.

c'''. The *Upper Ludlow* Division consists mainly of Calcareous Sandstone. The fossils are of common Silurian types, and, as in the last Division, abundant.

c''''. Above these beds, occurs the Ludlow "*Bone-bed*," which, varying in thickness from one inch to less than a foot, has been traced from Ludlow for 45 miles into Gloucestershire. It abounds with the remains of *Fishes*, all of the *heterocercal* class, but numbering only five genera and eight species. This bone-bed is the oldest instance of the remains of fishes occurring as an accumulation. In a bed overlying this bone-bed, occur the first indications of the existence of a *land plant*.

c'''''. The Downton Sandstone (or the "Tilestones") is the surmounting Formation of the Ludlow Group; and this is chiefly remarkable for the appearance in numbers of *Crustacea* of a type but sparingly represented in the rocks which preceded them: they occur in great numbers (no less than six genera and 22 species) in beds of this group; but they reached a more advanced development as to size during the succeeding Period; in the notice of which they will be again referred to.† Two genera and three species of *Fishes* also occur in this Formation.

c''''''. The total thickness of the Upper Ludlow Division is 900 feet.

* Greek—"*heteros*," different, and "*kerkos*," a tail.

† See forward, Sec. 14, *c*, p. 69.

d. Stratigraphical data would lead to the conclusion that the Downton Sandstone is a passage bed between the Silurian and the Devonian Systems: but this view is not completely supported by Palæontological evidence; for, of no less than 500 species contained in the Ludlow *fauna*, only some 25 pass up into the lowest Devonian rocks—still, it is significant that these include 7 species of Fishes and 6 of the then recently introduced Crustacea, referred to on the last page.

e. The following Table of the known Families and Species of the *fauna* of the great Silurian System, compiled from the Table of Fossils in the last edition of *Siluria* and other sources, will afford evidence of the great advance in the number and variety of Life-forms which characterized this remote period of the Earth's physical history:—

Table of Species of the Silurian System.

	Species.		Species.
Amorphozoa *	19	Brought forward	685
Graptolitidæ	107	Brachiopoda	204
Actinozoa † (Corals)	88	Conchifera	130
Echinodermata	83	Gasteropoda	97
Annelida	38	Pteropoda	27
Cirripedia ‡	1	Heteropoda	22
Trilobita	230	Cephalopoda	79
Other Crustacea	86	Pisces	11
Polyzoa	33		
Forward	685	Total	§1255

* Greek—"*a*," without, "*morphe*," form, "*zoon*," an animal—sponges, &c.

† Gk.—"*aktin*," a ray, "*zoon*," an animal; because of the radial structure of this class of organisms.

‡ Latin—"*cirrus*," a curl, and "*pedes*," feet; curl-footed—a class of *Multivalve Crustacea*, having curled tentacles, to which the modern *Balanus* or *Barnacle* belongs.

§ These numbers have been increased by more recent discoveries.

e'. It is to be noticed that the *Brachiopoda*, which preceded the Conchifera in age, have hitherto greatly exceeded them in numbers: their relative numerical proportion, however, in succeeding periods, gradually approached equality, became reversed, and ultimately so changed that the Brachiopoda only form one forty-fourth part of the Bivalve *fauna* of the present time.

12. The DEVONIAN and OLD RED SANDSTONE System.

a. A broad natural distinction separates this System into two great and probably *synchronous* * Divisions—that which had its origin in *marine* deposition, and that which consists mainly of *fluviatile* and *lacustrine* Formations.

b. The entire System was formerly included in the term "Old Red Sandstone"; but, when the distinction as to the origin of the two series came to be established, the term "*Devonian*" was adopted for the marine series, as it is chiefly developed in Devonshire, and that of the "*Old Red Sandstone*" was reserved for the very extensive fluviatile and lacustrine Formations of the same period which occur in Scotland, Wales, and elsewhere.

c. Both the Devonian and Old Red Sandstone Divisions have been sub-divided into *Lower*, *Middle*, and *Upper*; but an explanation of the reasons for such a sub-division would necessitate a treatment too lengthy for the scope of this Work.

13. The Formations of the *Devonian* Division reach their greatest aggregate thickness (from 15,000 to 18,000 feet) in North Devonshire and West Somersetshire.

a. Their probable original *area* has been described by Mr. Etheridge † as having been bounded on the North by a

* Greek—"*syn*," with, "*chronos*," time; at the same time.

† In an exhaustive Memoir on "The Physical Structure of West Somerset and North Devon," including "Devonian Rocks and Fossils."—*Quart. Journ. Geol. Soc.*, 1867, vol. xxiii., pp. 568–698.

line coincident with the latitude of the Mendip Hills in Somersetshire, as having ranged Eastwards to Coblentz on the Rhine, Westwards to the South coast of Ireland and over a region now covered by the Atlantic, and Southwards beyond the Southern Slopes of the Pyrenees.

b. The Devonian *fauna* is very abundant: it comprises—3 genera of *heterocercal Fishes*,* 5 of *Trilobites*, and a magnificent series of *Corals*; of *Mollusca*—27 genera of *Brachiopoda*, 21 of *Conchifera*, 13 of *Gasteropoda*, 1 of *Pteropoda*, 2 of *Heteropoda*, and 6 of *Cephalopoda* † (including *Nautilus*,‡ *Clymenia*,§ and *Goniatites*‖—all now for the first time occurring; the last being allied to and foreshadowing the long-after introduced *Ammonites* ¶).

14. The *Old Red Sandstone*, or fluviatile and lacustrine Division, has a wide spread in Scotland. It crosses the country in a broad belt from the North-Sea coasts of Forfarshire to the Firth of Clyde; and it occurs in Eastern Ross and Sutherland, throughout Caithness and the Orkneys, in Herefordshire, Wales, and Ireland. It occupies in Russia an area larger than that of the British Islands collectively, extends over wide districts in the United States and

* Of the family of *Placoids*, to which the living Sharks, &c., belong.

† Etheridge—*Quart. Journ. Geol. Soc.*, 1867, vol. xxiii., pp. 616–634.

‡ Greek—"*nautilos*," a second name given by Aristotle to the shell *Argonaut*, from "*argo-nautes*," a sailor of the ship Argo, because this Cephalopod was mistakenly thought to float upon the surface of the sea with its arms dilated for sails, like a ship. The Nautilus is represented by a few species still existing in tropical seas.

§ Latin—"*Clymene*," the classical name of a Sea-nymph.

‖ Gk.—From "*gonia*," an angle; on account of the zigzag lines which mark its shell.

¶ From the name of the Libyan deity Jupiter Ammon, on account of its likeness to the curled ram's horns with which the head of the latter was furnished. The word "*ammon*" is said to be Egyptian.

Canada, and has been found even as far North as Bear Island (74° North Latitude); some fossil Plants from which remote Arctic locality having been determined by Professor Heer * to be identical in species with land Plants from the Old Red Sandstone of Kilkenny.†

a. The aggregate *thickness* of all the Formations of the Old Red Sandstone cannot be much less than 10,000 feet.

b. The *fauna* of the Old Red Sandstone is not nearly so abundant as that of the Devonian, and of quite a different kind; as is clearly indicated by the following Table :—

Comparative Table of Species of the Devonian and Old Red Sandstone Faunas.‡

	Amorphozoa.	Actinozoa (Corals).	Echinodermata.	Annelida.	Crustacea.	Insecta.	Polyzoa.	Brachiopoda.	Conchifera.	Gasteropoda.	Pteropoda.	Heteropoda.	Cephalopoda.	Pisces.	Totals.
Devonian	9	53	21	2	13	..	13	99	58	46	1	9	52	3	379
Old Red Sandstone	..	..	..	2	21	1	1	..	1	..	..	..	..	113	139

b'. As is shown by the foregoing Table, *Fishes* had by far the preponderance in the Old Red Sandstone fauna. The 113 species represent no less than 41 genera; of which 4 genera and 7 species had been continued on from the highest Division of the Silurian System. All these Fishes had the heterocercal tail.

b''. The earliest genus known is the *Pteraspis*,§ a form of the Family *Cephalaspidæ*; which derived their name from the fact that the head was covered with a kind of shield, which varied in size and character in the various

* Of Zurich—one of the greatest authorities in Fossil Botany.

† See *ante*, Pt. I., Sec. 38, page 37.

‡ Etheridge—*Quart. Journ. Geol. Soc.*, 1867, vol. xxiii., p. 615.—It is probable that recent discoveries may have enhanced some of these numbers.

§ See *ante*, page 62.

genera so classed, but was most largely developed in the typical genus *Cephalaspis** (or "buckler-headed"), the fossil head-shields of which have been frequently mistaken for those of Trilobites. The body of *Cephalaspis*, and that of some allied genera, was covered with a series of segment-like plates (a kind of plate-armour), while that of *Pteraspis* and its congeners was clothed in scales.

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to Hugh Miller,* "and at least as bulky as a large Porpoise"), and the fossil remains of which have been found also both in Russia and North America.

b''''. These old *ganoid* Fishes are represented by a few species living in North American and African lakes and rivers; but which are so exceptional that, out of about 9,000 species of living fishes known, they only number 9 species.

c. Equally worthy of consideration are the *Crustacea* of this Period (mostly very large) which, with some others (the *Xiphosura*) occurring later, have been classed by Woodward † under the order *Merostomata*.‡ These Crustaceans, although more numerous in the latest beds of the Upper Silurian System (the Downton Sandstone and equivalent Scotch Formations) § attained to their greatest size in the Old Red Sandstone Period: they have been termed collectively the *Euryptidæ*.

c'. The largest species *Pterygotus* ‖ *Anglicus* (which is peculiar to the Old Red Sandstone) reached a length exceeding 5 feet and a breadth of more than 15 inches, dimensions much in excess of those of any living Crustacean. Fragments of this fossil consisting only of the anterior portion are frequently found, and these have been termed by Scotch quarrymen "*Seraphim*," from a fancied resemblance to the usual tombstone type of seraphic beings.

c''. Other genera are—*Slimonia* ¶ (only occurring, how-

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‡ Greek—"*meros*," a thigh, and "*stoma*," a mouth; on account of the peculiar structure of their *jaw-feet*.

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ever, in Upper Silurian Formations), which was from 3 feet to 4 feet in length; *Stylonurus* * (species of which occur both in the Upper Silurian and Devonian), one specimen of which measures 3 feet 4 inches; and *Eurypterus*,† one of which was about 20 inches in length. The last genus had the greatest range both in time and area—in the former, from the Upper Silurian, all through the Old Red Sandstone, into the Lower Carboniferous period; and in the latter, from the United States and Canada, to Great Britain, the Islands of Gothland and Oesel, to Rhenish Prussia, Bohemia, Poland, and Russia.

c'''. Certain fossils, at first thought to be fruits and named *Parka decipiens*, which have been found in the higher beds of the Upper Silurian and the lower beds of the Old Red Sandstone, have since been determined to be the *ovisacs* of these large Crustaceans, which are closely allied to the living King-Crabs of the East coast of North America, the coast of China, and the Sea of Japan.

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d. The *one Molluscous shell* of the Old Red Sandstone has been found in Ireland, is of the fresh-water genus *Anodonta*,§ and was allied to the living Mussel of our rivers and lakes.

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e. Insects (and those the earliest which have been found) occur in a Formation of this Division at St. John's, New Brunswick. They consist of four species of *Neuroptera**; one of which is a large *Ephemera*,† having an expanse of wing of five inches.‡

f. Remarkable as is the *fauna* of the Old Red Sandstone Period, its vegetable kingdom, or *flora*, is no less worthy of observation. As many as 80 plants from its European area have been identified; while no less than 120 have been noted by Principal Dawson as occurring in America.§ These are all of land kinds, and nearly allied in genera to plants of the succeeding Carboniferous System, and include even plants of as high an order as that of the *Coniferæ*.‖

g. Professor Ramsay has stated his belief that the Old Red Sandstone represents a great continental area, diversified by the presence of fresh-water lakes, like those of America, and of salt-water lakes or inland seas like the Caspian and the Dead Seas; and that the uppermost beds of the Silurian System are *passage-beds* ¶ marking the transition from marine conditions to the continental and lacustrine conditions which characterized the area of the Old Red Sandstone.** These views are supported to some extent by the evidence afforded by the *fauna* and the *flora* of the periods and areas involved.

* Greek—"*neuron*," a nerve, and "*pteron*," a wing; insects having membranous wings with finely reticulated nerves, such as the Dragon-fly, &c.

† Gk.—"*ephemeros*," lasting but a day; short-lived insects, such as the May-fly, called also the "Day-fly."

‡ Lyell's *Student's Elements*, 1874, p. 453. § *Ibid.*

‖ Professor Göppert—*Quart. Journ. Geol. Soc.*, vol. xvi.—*Coniferæ*, trees bearing cones.

¶ See forward, Sec. 20, *a*, page 88—*Rhætic Beds.*

** *Vide Quart. Journ. Geol. Soc.*, 1871, vol. xxvii., p. 243; and Lecture at the *Royal Institution.*

15. The Carboniferous System.

This System has been divided into the *Lower* and *Upper* Carboniferous Series.

16. The *Lower Carboniferous Series.*

a. Immediately overlying the highest beds of the Old Red Sandstone, as seen near Clifton and other places bordering the Bristol Coal-field, is a "*bone-bed*," almost entirely made up of bony fragments and teeth of *Placoid Fishes.*

b. Over this, and in some localities forming the base of the Carboniferous System, and presenting occasionally "a perfect blending and continuity" with the Old Red Sandstone,* are beds known as the *Lower Limestone Shales*, which have a thickness varying from 150 feet to 500 feet. In Scotland, these are represented by the *Calciferous Grit* Series, which is of great thickness.

c. The lowest important Formation, however, of this Series, is the *Carboniferous* (or *Mountain*) *Limestone*, which attains in Derbyshire and Yorkshire to a thickness of at least 5,000 feet. It consists chiefly of rocky strata of coarse texture, sometimes almost crystalline, interspersed, in the English Northern Counties and in Scotland, with beds of "shale, sandstone, and coal." †

c'. Some of the calcareous beds, often several hundreds of feet in thickness, are almost made up of fragments of the stony skeletons of *Crinoids* (or "sea-lilies"): in some bands, however, examples in a more or less perfect condition are not unfrequent, and represent many new genera.‡

Another remarkable form belonging to the same class of

* Professor Jukes—*Manual of Geology*, page 512.

† Hull—*Coal-fields of Great Britain*, 1873, page 81.

‡ A form of Crinoid has been thus described:—"This animal (one of a singular group) was planted upon a stony but flexible column, nearly cylin-

Echinodermata was the genus *Palæchinus*,* which greatly resembled the living Echinus or Sea-urchin.

c''. Other beds are chiefly rich in *Corals*, which agree in general character with those of preceding Systems, but exhibit differences which mark a line of distinction between, and divide into two groups, Palæozoic and more recent Corals. The number of Corals of the Carboniferous age, as classified by Edwards and Haime,† amounts to 76 species, of which 43 are British.

c'''. Several species of *Trilobites*, chiefly of the genus *Phillipsia*,‡ and two species of *Eurypterus*, occur in and disappear with this Formation.

c''''. *Fish* remains are very abundant in the Carboniferous Limestone, more than 70 species being known. These are chiefly of shell-crushing genera—the palates having been furnished with flat plate-like teeth, arranged like *tesseræ* in a pavement, as is the case in the living *Cestracion* § *Phillippi*, or Port Jackson Shark. The flat surface of such teeth of *Psammodus porosus* of this Formation was more than an inch and a quarter square. Another genus had teeth of the same

drical, and attached at its base to the solid rock. From the pouch, which is divided into five parts, as many pairs of smaller columns proceed, and each of these ten columns immediately splits itself into two, so that there are twenty movable arms immediately above the body, each of them being provided with a number of fingers, made up of similar small stony columns, admitting of considerable motion; by means of which, food could be obtained and conveyed at once to the stomach of the animal. It is calculated that nearly 30,000 separate pieces of stone exist in one skeleton of this singular creature."—*General View of Geology*, 1853.

* Greek—"ancient sea-urchin."

† Monograph, *Palæontological Society*, page 150.

‡ Named after Professor Phillips, by the late Gen. Portlock, F.R.S., of the Geological Survey of Ireland.

§ The *Cestraciontidæ* were an early sub-family of Sharks, of which *C. Phillippi* is the only living representative.

nature, but twisted or "distorted"—indicating that the prey of this genus differed from that of allied genera.

c''''. Very many forms and many new species of *Mollusca* occur in the Carboniferous Limestone:—*Brachiopoda* (some species of the prolific genus *Productus* * acquiring a great size), *Conchifera*, the *Heteropod* (*Nucleobranch*†) *Bellerophon* more than 20 species, although not found in later Formations), *Gasteropoda* (of which *Euomphalus* ‡ is a characteristic genus having a chambered whorl-shell, the chambers marking stages of growth resembling various forms of Cephalopoda, but not having any connecting siphuncle), and *Cephalopoda*, which included *Orthoceras* and *Goniatites*, both disappearing in the marine beds of this Series.

d. The Carboniferous Limestone passes up into a series of "shales and grits," which Professor Phillips called the *Yoredale Series*, from a locality in Yorkshire, where they are about 1,000 feet thick; but in Lancashire, they attain to a thickness of nearly 5,000 feet.

e. The Yoredale beds, in like manner, pass up, without any separating plane of "unconformity," into the *Millstone Grit*; which, in the central and Northern Coal-fields of this country, attains to a thickness of several thousand feet. It acquires its name from the use to which its stone has been commonly applied: this use is of such ancient origin as to have been common during the occupation of Britain by the Romans, who frequently worked up into handstones and querns fragments of this rock found in the Boulder Clay,‡

* Latin—"*producere*," to extend; one valve being prolonged beyond the other.

† Latin—"*nucleus*," a kernel, &c., and "*branchiæ*," gills; in reference to the peculiarity of the respiratory organs.

‡ Greek—"*eu*," well, and "*omphalus*," the umbilicus or centre, such as the boss in the middle of a shield; well coiled round the centre.

§ See forward, Sec. 53, par *b*''.

in localities far removed from any existing site of the original Formation.* The Millstone Grit is sometimes traversed by thin seams of Coal.

f. Above the Millstone Grit, are the *Lower Coal Measures*, or *Gannister Series*†; which near Halifax in Yorkshire, reach a thickness of nearly 1,400 feet. They have been classed by Mr. Hull in the Lower Carboniferous Division because their fossils agree mainly with those of that Division; although perhaps in England they are as wide spread as and generally underlie the Middle and Upper Coal Measures. The fossils of the Gannister beds are *marine*.

Table of Marine Species of Mollusca occurring in the Lower Carboniferous Division, and chiefly in the Carboniferous Limestone.

	Species.		Species.
Polyzoa	55	Brought forward	720
Brachiopoda	157	Pteropoda	1
Conchifera	334	Nucleobranchiata	29
Gasteropoda	174	Cephalopoda	145
Forward ..	720	Total ..	895

Of these, only 40 species were common to the Old Red Sandstone System—24 Bivalves (chiefly Brachiopoda), 7 Gasteropods, and 9 Cephalopods.

17. The *Upper Carboniferous Series*—comprises the *Middle* and *Upper Coal Measures*, from which the larger proportion of our Coal Supply in England and Wales is obtained.

* Several millstones are in the possession of the Author which have been found by him on the site of a Roman cemetery at Duston, Northamptonshire, fashioned by Roman settlers from Boulders of Millstone Grit obtained from the thick Boulder Clay of the district.

† Name given by Professor Phillips, from the local name of one of the intermediate stone beds—*vide* "Geology," in Encyclopædia Metropolitana.

genera so classed, but was most largely developed in the typical genus *Cephalaspis** (or "buckler-headed"), the fossil head-shields of which have been frequently mistaken for those of Trilobites. The body of *Cephalaspis*, and that of some allied genera, was covered with a series of segment-like plates (a kind of plate-armour), while that of *Pteraspis* and its congeners was clothed in scales.

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f. Remarkable as is the *fauna* of the Old Red Sandstone Period, its vegetable kingdom, or *flora*, is no less worthy of observation. As many as 80 plants from its European area have been identified; while no less than 120 have been noted by Principal Dawson as occurring in America.§ These are all of land kinds, and nearly allied in genera to plants of the succeeding Carboniferous System, and include even plants of as high an order as that of the *Coniferæ*.‖

g. Professor Ramsay has stated his belief that the Old Red Sandstone represents a great continental area, diversified by the presence of fresh-water lakes, like those of America, and of salt-water lakes or inland seas like the Caspian and the Dead Seas; and that the uppermost beds of the Silurian System are *passage-beds* ¶ marking the transition from marine conditions to the continental and lacustrine conditions which characterized the area of the Old Red Sandstone.** These views are supported to some extent by the evidence afforded by the *fauna* and the *flora* of the periods and areas involved.

* Greek—"*neuron*," a nerve, and "*pteron*," a wing; insects having membranous wings with finely reticulated nerves, such as the Dragon-fly, &c.

† Gk.—"*ephemeros*," lasting but a day; short-lived insects, such as the May-fly, called also the "Day-fly."

‡ Lyell's *Student's Elements*, 1874, p. 453. § *Ibid.*

‖ Professor Göppert—*Quart. Journ. Geol. Soc.*, vol. xvi.—*Coniferæ*, trees bearing cones.

¶ See forward, Sec. 20, *a*, page 88—*Rhætic Beds.*

** *Vide Quart. Journ. Geol. Soc.*, 1871, vol. xxvii., p. 243; and Lecture at the *Royal Institution.*

15. The Carboniferous System.

This System has been divided into the *Lower* and *Upper* Carboniferous Series.

16. The *Lower Carboniferous Series.*

a. Immediately overlying the highest beds of the Old Red Sandstone, as seen near Clifton and other places bordering the Bristol Coal-field, is a "*bone-bed*," almost entirely made up of bony fragments and teeth of *Placoid Fishes.*

b. Over this, and in some localities forming the base of the Carboniferous System, and presenting occasionally "a perfect blending and continuity" with the Old Red Sandstone,* are beds known as the *Lower Limestone Shales*, which have a thickness varying from 150 feet to 500 feet. In Scotland, these are represented by the *Calciferous Grit* Series, which is of great thickness.

c. The lowest important Formation, however, of this Series, is the *Carboniferous* (or *Mountain*) *Limestone*, which attains in Derbyshire and Yorkshire to a thickness of at least 5,000 feet. It consists chiefly of rocky strata of coarse texture, sometimes almost crystalline, interspersed, in the English Northern Counties and in Scotland, with beds of "shale, sandstone, and coal." †

c'. Some of the calcareous beds, often several hundreds of feet in thickness, are almost made up of fragments of the stony skeletons of *Crinoids* (or "sea-lilies"): in some bands, however, examples in a more or less perfect condition are not unfrequent, and represent many new genera.‡

Another remarkable form belonging to the same class of

* Professor Jukes—*Manual of Geology*, page 512.

† Hull—*Coal-fields of Great Britain*, 1873, page 81.

‡ A form of Crinoid has been thus described:—"This animal (one of a singular group) was planted upon a stony but flexible column, nearly cylin-

Echinodermata was the genus *Palæchinus*,* which greatly resembled the living Echinus or Sea-urchin.

c''. Other beds are chiefly rich in *Corals*, which agree in general character with those of preceding Systems, but exhibit differences which mark a line of distinction between, and divide into two groups, Palæozoic and more recent Corals. The number of Corals of the Carboniferous age, as classified by Edwards and Haime,† amounts to 76 species, of which 43 are British.

c'''. Several species of *Trilobites*, chiefly of the genus *Phillipsia*,‡ and two species of *Eurypterus*, occur in and disappear with this Formation.

c''''. *Fish* remains are very abundant in the Carboniferous Limestone, more than 70 species being known. These are chiefly of shell-crushing genera—the palates having been furnished with flat plate-like teeth, arranged like *tesseræ* in a pavement, as is the case in the living *Cestracion* § *Phillippi*, or Port Jackson Shark. The flat surface of such teeth of *Psammodus porosus* of this Formation was more than an inch and a quarter square. Another genus had teeth of the same

drical, and attached at its base to the solid rock. From the pouch, which is divided into five parts, as many pairs of smaller columns proceed, and each of these ten columns immediately splits itself into two, so that there are twenty movable arms immediately above the body, each of them being provided with a number of fingers, made up of similar small stony columns, admitting of considerable motion; by means of which, food could be obtained and conveyed at once to the stomach of the animal. It is calculated that nearly 30,000 separate pieces of stone exist in one skeleton of this singular creature."—*General View of Geology*, 1853.

* Greek—"ancient sea-urchin."

† Monograph, *Palæontological Society*, page 150.

‡ Named after Professor Phillips, by the late Gen. Portlock, F.R.S., of the Geological Survey of Ireland.

§ The *Cestraciontidæ* were an early sub-family of Sharks, of which *C. Phillippi* is the only living representative.

those forms as we should associate with a moist land surface and a terrestrial or marsh vegetation include—numerous *Insects* (Crickets and Cockroaches, Centipedes, Scorpions * and allied genera, several genera of Beetles, very large White Ants, a large species allied to a Spider, a Grasshopper or Locust, the wing of an Ephemera measuring 7 inches from tip to tip, a Mantis,† &c.), *Land Snails* (a Pupa identical in structure with a modern form, and a small Helix): a shelled *Annelid* (*Spirorbis*) occurs on Fern-fronds, and a coprolite, possibly of a *land Reptile*, has been found.

j'. The aquatic forms consist of—fresh-water Bivalves allied to *Cyrena* and *Unio*, minute *Entomostracan Crustacea* (*Leperditia*, *Estheria*, &c.),‡ three genera of *Crustacea* of the order *Merostomata*, (one form, *Belinurus Trilobitoides*,§ being apparently intermediate between the Trilobite and the living King Crab), and *Reptiles allied to Fishes*‖ in 17 genera, all to be grouped with the associated typical genus *Archegosaurus*.¶

k. Mr. Hull has indicated the probability that the Coal Measures of the British Islands originally constituted only three great Coal-fields; that a Northern Coal-field comprised the whole of the Scotch, North of England, North Wales, and Midland Coal-fields of the present time; and that this was separated from a Southern Coal-field by a "barrier" of elevated land-surface, which extended—from the Western boundary of Wales, through Shropshire and

* *Vide* description of first true Scorpion from English Coal Measures, by H. Woodward, Geol. Soc. Meeting, Nov. 3, 1875, *Quart. Journ. Geol. Soc.*, 1876, vol. xxxii., part 1.

† *Ibid.*

‡ See *ante*, page 52, note (‡).

§ Hull's *Coal-fields of Great Britain*, 1873, frontispiece, fig. 10.

‖ Owen's *Palæontology*, p. 195.

¶ Greek—"*archegos*," beginning, and "*sauros*," a lizard; a primordial lizard.

Herefordshire, Eastwards along the Southern margin of the Staffordshire and Warwickshire Coal-fields, through Northamptonshire, with a turn to the North-East into Leicestershire (where its presence is manifested by the protruding Cambrian rocks of Charnwood Forest), and through Lincolnshire to the Humber.

k'. The Coal-field South of this "barrier" would comprise the present Coal-fields of South Wales and of the South-Western districts of England. It probably occupied nearly the whole area of the Southern Counties, and ranged into France and Belgium, and beyond.

k''. The third great Coal-field comprised the existing Coal Measures of Ireland, and occupied nearly the whole area of the island. It is not improbable that this Coal-field was connected with, and an extension of, the Great Northern Coal-field of Britain.

l. Towards the close of the Carboniferous Period, a series of terrestrial movements, resulting from lateral pressure, occurred throughout the South and North districts of England; which forced the Carboniferous strata into a series of *anticlinal* and *synclinal* flexures, ranging East and West, accompanied by many fractures and faults. These were followed by great denudation, which swept away vast tracts of Coal Measures which had been elevated by these causes.

l'. These changes occurred previously to the setting-in of the succeeding Permian System; the deposits of which were distributed horizontally "over the bent and denuded edges and surfaces of the Carboniferous strata": other movements having a North and South direction, "accompanied by denudation, chiefly along the arches or *anticlinal* axes," occurred at the close of the Permian but before the

commencement of the Triassic* Period; leaving as remnants Coal-basins and Coal-fields to a great extent identical with those now existing—and thus was completed the eventful history of the long period of the Carboniferous era.†

18. The PERMIAN System.

a. The *Lower Permian* beds have an aggregate thickness of 3,000 feet. In this country, they occur chiefly in Durham, Yorkshire, Nottinghamshire, and Warwickshire, and are mainly characterized by their Plant-remains. In the lowest beds are some few plants found also in the Coal Measures; but in the higher beds these successively disappear, until the *flora* is entirely distinct. Other organic remains are generally absent, but *Worm* tracks and foot-prints of *Reptiles* are found.

b. The *Middle Permian* or *Magnesian Limestone* (deriving the latter name from the mineral character of many of its beds) has an aggregate thickness in this country of about 850 feet, being chiefly developed in the North-East of England. It is very fossiliferous, its most remarkable Life-forms being those of *Polyzoa*, *Brachiopoda*, and *Fishes*, the latter comprising numerous genera and species, but all having the heterocercal tail.

c. The *Upper Permian* has its greatest thickness in Cumberland (about 600 feet). It consists of red sandstones and clays, with occasional beds of gypsum. It is not noticeably fossiliferous.

d. The *fauna* of the Permian Formations in this country numbers 147 species, of which 77 are *Mollusca*, including

* See forward, page 85, Sec. 19.

† *Vide* Hull—*On the Triassic and Permian Rocks of the Central Counties of England*, Mem. Geol. Survey, 1869, p. 109; also *Coal-fields of Great Britain*, 1873, p. 462, *et seq.*, and Map, plate xii.—To the latter most valuable Work, I am indebted for much information (other than that acknowledged) embodied in this short account of the Carboniferous System.

25 *Gasteropoda* and only one *Cephalopod*, a Nautilus. Of these, none lived on into later periods, and of only one group of bivalves (*Brachiopoda*) had species existed in older times.

B. Secondary Strata—Mesozoic Life Period.

19. The Triassic (or New Red Sandstone) System.

It was stated in the last Section that no species of the *fauna* of the Permian period continued on into subsequent periods. The few Life-forms which occur in the lowest Triassic beds as a group are sufficiently distinct from those which had preceded them to mark a well-defined line of separation between the Palæozoic and Mesozoic Life Periods.

Of the three great Triassic Divisions—the *Bunter*, the *Muschelkalk*, and the *Keuper*,—only the first and the last occur in this country. These, in frequent vertical juxtaposition, range irregularly, from the Tees Mouth and Hartlepool in Durham, in a South-Westerly direction to the estuary of the Severn in Gloucestershire; they have a wide-spread development to the North-West, reaching to the mouths of the Dee, the Mersey, and the Ribble; they appear occasionally South of Gloucestershire; and the lower Division, the Bunter, stretches Southwards, through Somersetshire and Devonshire, to the English Channel. The Trias occurs also in Scotland.

a. The *Bunter* is characterized by the occurrence of indications (by foot-prints only) of a large species of *Reptile*, probably of the Batrachian Order (remotely allied to the Toad), which, from the likeness of those prints to the human hand, has been called "*Cheirotherium*"*; also, in its lowest beds near Bristol, two genera of *Reptiles* (perhaps terrestrial

* *Greek*—"*cheir*," the hand, and "*therion*," a wild animal.

or partially amphibious) allied to the less ancient *Dinosauria**; which in some particulars of their osseous structure were allied to Birds.†

a'. This Formation has a thickness of 1,500 feet in Warwickshire, and has there been found to include trunks of trees 18 inches in diameter, exhibiting rings of annual growth.

b. The *Keuper* (including the strata sometimes called the "Red Marl") attains a thickness of 3,450 feet in Cheshire,‡ and is remarkable for the immense deposits of *salt* which abound in that district. It also contains, in Nottinghamshire, valuable beds of rock *gypsum* or *alabaster* (sulphate of lime); which is largely quarried for the manufacture, by burning, of plaster of Paris.

b'. The Formation has yielded—a few land *Plants*, and *Fishes*; also traces and remains of numerous amphibious *Reptiles*, including a Batrachian form, which, from the peculiar structure of its teeth as seen in section, has been called by Professor Owen "*Labyrinthodon*" §; a form "having a small bird-like skull and jaws without teeth,"‖ called "*Rhynchosaurus*" ¶; and three terrestrial *Reptiles*, one closely allied to a Reptile still living in New Zealand.**

* Greek—"*deinos*," terrible, and "*sauros*," a lizard; so called on account of the great size of the *Dinosaurians*.

† Woodward—"On Forms Intermediate between Birds and Reptiles," *Quart. Journ. Geol. Soc.*, 1873, vol. xxx., p. 11.

‡ "As ascertained by the measured sections of the Geological Survey." Hull—*On the Triassic and Permian Rocks of the Central Counties of England*, Mem. Geol. Survey, 1869, page 103.

§ Gk.—"*labyrinthos*," a labyrinth, and "*odous*" (gen. "*odontos*"), a tooth.

‖ Lyell's *Student's Elements*, 1874, p. 358; and Owen's *Palæontology*, p. 267. For general description, *ibid.*, p. 263.

¶ Gk.—"*rhynchos*," a beak, and "*sauros*," a lizard.

** Huxley—*Quart. Journ. Geol. Soc.*, 1869, vol. xxv., p. 147.

c. It is to be noted that, in the few *Fishes* found in the Trias, the "*homocercal*" form of tail for the first time occurs, and is the prevailing form in all subsequent Geological periods. Sir Chas. Lyell says, "The *homocercal* * Fishes, which comprise almost all the 9,000 species at present known living, have the tail-fin either single or divided; and the vertebral column stops short, and is not prolonged into either lobe."

d. The most remarkable remains found in the Keuper, however, are the teeth of a small *Marsupial Mammal*, called "*Microlestes*"—from the Greek "*mikros*," little, and "*lestes*," a robber, as belonging to the "rapacious" group of Marsupialia. These constitute the oldest known traces of Mammalian life upon the Earth, and present the lowest form of Mammalian life; the young of which are produced in an immature condition, and matured in a pelvic pouch—hence "*Marsupialia*," from the Latin "*marsupium*," a pouch. The Marsupialia of the present time only exist in Australia, a few of the Indian islands, and in America.

e. Few traces of marine life have been detected in the Keuper and Bunter of this country: these Professor Ramsay considers to have been the deposits—the former of salt lakes, like the Caspian and Dead Seas, and the latter in lakes variably of salt, brackish, and fresh water.†

f. In the German Muschelkalk (the intermediate Formation of the Trias), the abundant fossils are all of *marine* origin; the most noticeable form being that of "the *Cephalopodous* genus *Ceratites*,‡ which formed a remarkable link

* Greek—"*homoios*," like, and "*kerkos*," a tail; meaning that the two lobes of the tail are alike.

† *Physical Geology of Great Britain*, 3d edit., Table, p. 26; *ibid.*, p. 82: see also *Quart. Journ. Geol. Soc.*, 1871, pp. 189–241.

‡ Gk.—"*keras*," a horn, from its shape; the horn fossil.

between the Palæozoic *Goniatites* (which disappeared with the Carboniferous Limestone) and the Mesozoic *Ammonites*"*—that multiform genus, shortly to appear in the Liassic period.

g. In America, foot-prints said to be of *Birds*, have been found in beds of the Triassic period. *If* they are foot-prints of Birds, they are doubtless those of large wingless or flightless Birds, some four times the size of those of the existing Ostrich, and are the earliest traces of the existence of any kind of Bird which have yet been discovered: a question, however, has been raised as to whether these foot-prints are not really of *Reptilian* origin.

20. The RHÆTIC Beds.

a. These beds are also called—by the Government Geological Survey, the "Penarth Beds," from Penarth, near Cardiff, where they attain a considerable thickness; and by Dr. Wright, the "*Avicula contorta* Beds," from the prevalence of that fossil in the principal bed of the group.

b. The Rhætic beds are regarded as "*beds of passage*" between the Triassic and the Liassic Systems.

b'. It cannot be conceived that there could have been a point in time at which the Period of any System or Formation definitely ceased and the Period of any succeeding System or Formation as definitely commenced. One must have merged into the other, and Life-forms have been gradually transmuted into or superseded by other Life-forms, during a connecting Period of longer or shorter duration; and such connecting or transitional Period must have had a stratigraphical representative in "*passage-beds*," either somewhere remaining or lost by denudation.

b''. The continuity of the Cambrian and the Silurian

* Jukes' *Manual of Geology*, p. 560.

Systems is so complete that the exact line of separation was in early days a matter of dispute between Sedgwick and Murchison, and is even now under discussion.* The passage of the Silurian into the Devonian, of the Devonian into the Carboniferous, and of the Carboniferous into the Permian Systems, in each case, is partially indicated (but in a greater or lesser degree) by the continuing on of some Life-forms of the earlier System into the succeeding System, and by the commingling for a time of the Life-forms of both; which Life-forms would thus occupy, as it were, a kind of "borderland" between the two Systems.

b'''. No indication of a "passage" of the Permian System into the Triassic System has yet been discovered; but that of the Triassic into the Liassic is completely represented by the Rhætic beds. "Passage-beds," and more or less distinct indications of "passage," and some abrupt breaks, occur between subsequent Systems and Formations, which will be referred to in Sections to come.†

c. The fossils of the Rhætic beds are *marine*. The most characteristic of the *Mollusca* is the bivalve *Avicula contorta*, referred to above. Some of the species are continued on into the Lias. *Marsupial* teeth have also been found in this Formation. The Rhætic group is chiefly allied to the previous System by the contents of a bone-bed or *breccia*,‡ which occurs in Devonshire, Gloucestershire, West

* See *ante*, p. 53, "NOTE."

† To establish doubtful "passage-beds," and to discover "passage-beds" where none are now known, would be good work for rising Geologists; for, by this means, "the fragmentary character of the Geological record" (as spoken of by Sir Chas. Lyell) would be gradually if only partially repaired, and an approach made to that "*continuity*" which was the text-word of Mr. Justice Grove in his Presidential Address at the Meeting of the British Association at Nottingham in 1866.

‡ From the German "*brecken*," to break, the bed being made up of fragments.

Somersetshire, and Glamorganshire, exposed in cliffs bordering the Bristol Channel;* which contents consist of the remains of *Fishes* of genera common to the intermediate Division of the Trias, the marine Muschelkalk of Germany.

21. The Liassic System.

The Lias, although unbroken by any general plane of unconformity throughout the entire vertical series of its numerous beds, has been divided into three groups—the *Lower Lias* Clay and Limestone, the *Middle Lias* or *Marlstone* Rock-bed and underlying Sands, and the *Upper Lias* Clay and Sands. These stretch, as a constant series, in a belt across England, from the Dorsetshire coast on the South-West to the Northernmost point of the Yorkshire coast on the North-East.

a. The *Lower Lias* (which has a maximum thickness of 900 feet) is characterized by the first appearance of several new forms of *Mollusca*, such as—*Ostrea*, *Gryphæa incurva*, *Lima gigantea*, *Avicula cygnipes* (swan-footed), *Hippopodium ponderosum*, etc.; also by a peculiar *Crinoid*, having innumerable tentacular arms, and named therefore *Extracrinus Briareus*, from the classical hundred-armed Titan, Briareus.

b. In the *Middle Lias*, occurs commonly a large bivalve shell, having bold "*costæ*" or ribs, and called *Pecten equivalvis*, the two valves being nearly uniform; also numerous bivalve shells of the class *Brachiopoda*, called *Rhynchonella tetraëdra*†; and several *Star-fishes* (one, *Ophioderma*‡, having five attenuated and tortuous rays).

* At Axmouth, Westbury-on-Severn, the Aust Cliff, and other places.

† Greek—"*rhynchos*," a beak, "*tetra*," four, "*ëdra*," a base or seat; meaning four-sided.

‡ Gk.—"*ophis*," a snake, and "*derma*," skin; in allusion to the snake-like appearance of the rays.

b'. The Middle Lias reaches a thickness (rarely) of about 200 feet, and with some Upper beds of the Lower Lias, are extensively worked for iron-ore in the Cleveland district of North Yorkshire, and in Northamptonshire and Oxfordshire in the neighbourhood of Banbury.

c. The *Upper Lias* in several districts is 300 feet thick: in the neighbourhood of Northampton, it has yielded a peculiar clawless Lobster,* named by Mr. Woodward *Peneus Sharpii*;† and it is remarkable that this genus still lives in the Mediterranean. The *jet* of Whitby and Scarborough (bituminized fossil wood) is found in the clay of the Upper Lias.

d. At the base of the Upper and Lower Lias Divisions respectively, occurs a bed which is crowded with the remains of *Insects*, small Fishes, and Crustaceans, Ferns, Cycads, and leaves, brackish and fresh-water and in some places marine *Testacea*. The Insect remains have been found to include several genera and many species of Beetles, Grasshoppers, Dragon-flies, and May-flies.

e. The Liassic beds are in the main *marine* deposits: some, however, are *estuarine*; and the Insect-beds certainly are almost if not entirely of *fresh-water* origin.

f. The three Divisions of the Lias have together yielded more than 1000 species of *Mollusca*, including some 280 *Cephalopods*, of which nearly 200 are *Ammonites*, the remainder consisting (with one exception) of various species of the *Nautilus* and *Belemnite*. The *Ammonites* and *Belemnites*, as definite genera, make their first appearance in the Lower Lias. The different species of Ammonites have been found severally to have so limited a vertical range that

* Discovered by the Author—*vide* "Memoir on the Oolites of Northamptonshire," Pt. I., *Quart. Journ. Geol. Soc.*, 1870, vol. xxvi., p. 364.

† *Report of British Association*, 1868, page 74, plate ii., fig. 3.

they have been utilized for the division of the Liassic beds into "*zones*"—the Lower Lias into *seven* zones, the Middle Lias into *three* zones, and Upper Lias Clay into *one* or *two* zones.

f'. The word "*Belemnite*" is derived from the Greek "*belemnon*," a dart, on account of the shape of the internal shell, or "guard," the only portion of the animal which generally remains in a fossil state.* The Belemnite had a near affinity to the existing Cuttle-fish.

f''. *Fishes* abound in the Lias, as many as 120 species having been identified in the British beds alone. These are almost entirely *homocercal* in character, and have a generic affinity to those of the succeeding Oolitic System.

g. The Liassic Period was the era of colossal *Reptiles*. Its seas teemed with *Ichthyosauri* ("fish lizard"), *Plesiosauri* ("like a lizard"), and *Teleosauri* ("quite a lizard"). The last was a Crocodile, having affinity to the Gavial, or long-snouted Crocodile of the Ganges.

g'. A kind of *flying Lizard*, *Pterodactylus*,† is more rarely found. The wing of this flying Saurian consisted of a membrane extending from a fore-finger (which was elongated so as often to exceed the length of the neck and body of the animal) to the hind leg and tail, just like the wing of a Bat.

g''. There have been found in the Lower Lias the remains of a huge *terrestrial Lizard* of the *Dinosaurian*‡ group,

* There are several interesting specimens in the British Museum, and in the Museum of Practical Geology in Jermyn-street, London, in which the animal itself is more or less perfectly preserved; and these enabled Professor Huxley to write a *Monograph on the Structure of the Belemnitidæ*, published by the Geological Survey.

† Greek—"*pteron*," winged, and "*dactylos*," a finger; meaning wing-fingered.

‡ Greek—"*deinos*," mighty, marvellous.

called by Owen the *Scelidosaurus*,* and which (having been probably an herbivorous animal) would seem to foreshadow the gigantic *Iguanodon* and *Hylæosaurus* of the Wealden Series.†

g'''. The existence of all these genera of Reptiles apparently commenced in the Liassic period.

22. The SUPRA-LIASSIC or MIDFORD SANDS—*Passage-Beds.*

a. In these Sands, are commingled fossils characteristic of the underlying Upper Lias Clay (*Ammonites opalinus*, *A. insignis*, *A. radians*, etc.), and fossils characteristic of the overlying Inferior Oolite Formation (*Pholadomya fidicula*, *Gervillia Hartmanni*, *Hinnites abjectus*, *Myoconcha crassa*, etc.), together with some peculiar to the Sands themselves, such as *Rhynchonella cynocephala* ‡: they are held, therefore, to be *passage-beds* between the Upper Lias and Inferior Oolite, and to be the "stratigraphical representatives" of a transitional period which connected, and constituted the *continuity* of, the great Periods of the Liassic and Oolitic Systems. [See *ante*, Pt. II., Sec. 20, p. 88, *b*.]

b. These beds have their greatest thickness in Dorsetshire, Gloucestershire, and Somersetshire; in which counties, they first attracted the attention of Geologists: they were designated by the late Professor Phillips (who first described their transitional character), the Midford Sands, from the

* Gk.—"*skelis*," a limb; from its having greater power in the hind legs than most Saurians.

† *Vide* Owen's *Monograph of a Dinosaur of the Lower Lias*, *Pal. Soc.*, 1861–65. Also, see forward, Sec. 36, *a'*.

‡ Gk.—"*kyon*" (gen. "*kynos*"), a dog, and "*cephale*," the head; dog-headed.

Midford Valley in the last-named county, in which they are well shown.*

c. The Midford Sands have equivalents in Yorkshire † and Lincolnshire, and are probably importantly represented in the lower portion of the ferruginous beds of the Northampton Sand. ‡ They are of *marine* origin.

23. The Oolitic § or Jurassic System.

The Oolite System is divided into the *Lower*, *Middle*, and *Upper*.

A. The Lower Division comprises—the *Inferior Oolite*, the *Fuller's Earth*, the *Great Oolite* (including the *Stonesfield Slate* and equivalent Clays as its base, and beds equivalent to the *Forest Marble* and *Bradford Clay* of the West of England as its upper portion), and the *Cornbrash*.

24. The *Inferior Oolite*—

a. In the South-West of England, attains a thickness exceeding 250 feet: it is wholly *marine*, and is only ferruginous in a thin band which immediately overlies the passage-beds of the Supra-Liassic Sands. It consists of

* *Geology of Oxford*, p. 118; see also Dr. Wright "On Sands of the Inferior Oolite," *Quart. Journ. Geol. Soc.*, vol. xii., p. 292.

† *Vide* Phillips' *Geology of Yorkshire*, 3d edit., 1875, pp. 29, 33, 139.

‡ *Vide* Sharp's "Memoir on the Oolites of Northamptonshire," Pt. II., *Quart. Journ. Geol. Soc.*, 1873, vol. xxix., pp. 285, 286; also Judd's *Geology of Rutland*, 1875, p. 39.

§ The term "Oolitic" was originally applied to some of the beds of this System on account of the peculiar structure of their stone. A polished section of such stone shows that it consists of egg-shaped grains (formed of minute *nuclei* of silicious particles or shell-fragments enclosed in numerous concentric calcareous films) embedded in a calcareous matrix. This term, so appropriate to such beds, came to be applied to the whole System, comprising beds of sand, clay, shale, marl, etc.; but as to these it is a misnomer.

numerous beds, which differ much in mineral character, and comprise, variously, strata of—sand, sandstone, grit (a coarse sandstone), rag (a coarse shelly stone), flaggy limestones, soft calcareous (or limey) marls, pisolitic limestone (consisting of pea-like grains—"*pea-grit*"), and Oolitic limestone. In consequence of the persistent presence of particular species of Ammonites through certain ranges respectively (as in the Liassic System), these beds have been divided into the *Ammonites Murchisonæ* zone, the *A. Humphresianus* zone, and the *A. Parkinsoni* zone.

b. In the Midland Section of the Inferior Oolite (the typical development of the lower part of which occurs in Northamptonshire, and of the upper part in Lincolnshire), these beds assume very different conditions.*

b'. In the Lower Division of the *Northampton Sand* (the lowest beds of the Inferior Oolite throughout this area), occur the now famous ironstones of Northamptonshire. These represent a shallow sea of varying depth, occasionally littoral† or deltic (as shown by a band of ripple-marked slabs), and afford evidence of still further shallowing, until their conformable junction with an overlying estuarine deposit (designated by Mr. Judd the "*Lower Estuarine*"); the latter constituting the Upper Division of the Northampton Sand.

b''. Both Formations are traceable from Oxfordshire, through Rutland and Lincolnshire, into Yorkshire, where their equivalents are to be recognized—the Lower Division

* *Vide* Sharp—"Memoir on the Oolites of Northamptonshire," Pt. I., *Quart. Journ. Geol. Soc.*, 1870, vol. xxvi.; and Pt. II., *ibid.*, 1873, vol. xxix.—also Judd's *Geology of Rutland*, 1875, pp. 113–138.

† Sharp—"Memoir," Pt. I., p. 371.

in the ferruginous beds of *Rosedale*, *Glaizedale*, and the *Dogger*, and the Upper Division in the "*Lower Sandstone, Shale, and Coal*" of the same districts.*

b'''. In the Northern Division of Northamptonshire, a series of *marine* limestone beds, overlying the Lower Estuarine, appears near Kettering: at first it is a very thin deposit, but it rapidly increases in thickness in a North-Easterly direction, until in Mid-Lincolnshire it attains a thickness exceeding 200 feet. It passes on for some miles into Yorkshire, where it thins away. This Formation has been called the *Lincolnshire Limestone*,† and comprises various marly, shelly, and oolitic beds, which yield some of the most anciently quarried and finest building-stones in England. It has no known equivalent elsewhere, although it is nearly synchronous with (but perhaps a little later than) the limestones of the *Ammonites Humphresianus* zone of the West of England.

c. The Lincolnshire Limestone is based throughout the greater part of its area in Northamptonshire by a calcareo-silicious bed; which, upon exposure to frost, splits in the planes of its fine *laminæ* of stratification, and is called *Collyweston Slate*,‡ from the locality in which it is chiefly excavated: it is extensively used for roofing.

d. In Yorkshire, occurs a "*Grey Limestone*," of *marine* origin; formerly considered to be Great Oolite, but latterly by its fossils determined to be Inferior Oolite: it is probably a little higher in the scale than the Lincolnshire Limestone.

* Sharp—"Memoir," Pt. I., p. 356, *et seq.*; Judd's *Rutland*, p. 92; and Phillips' *Geology of Yorkshire*, 3d edit., 1875, pp. 33, 38.

† Sharp—"Oolites of Northamptonshire," Pt. II., *Quart. Journ. Geol. Soc.*, vol. xxix.; and Judd's *Rutland*, pp. 139–185.

‡ *Ibid.*, *ibid.*

e. The Inferior Oolite beds in the Western and Midland districts are characterized by certain *Brachiopoda*, especially *Terebratula fimbria* and *Rhynchonella spinosa*, and, amongst other Bivalves, by *Pholadomya fidicula*.

e'. The Northampton Sand has yielded many forms of *Mollusca* previously unknown; also a beautiful solitary specimen of a *Star-fish*, which has been named by Dr. Wright *Stellaster Sharpii*:* another form of *Stellaster* (*S. Berthandi*) has been found in a nearly equivalent bed in the South of France;† and these are the earliest examples of this genus which have been discovered. The scutal plate of an unrecognized species of *Teleosaurus* has been found, as have also, in two localities, a tooth and pelvic bones of two individuals of the *Megalosaurus* (from the Greek "*megalos*," great), a huge carnivorous land or amphibious Lizard (some examples at least 30 feet long‡), the osseous structure of which in some particulars was remotely akin to that of Birds.§

e''. In the Lower Estuarine, a Plant-bed (showing the plants as growing *in situ*) constitutes the only organic remains yet discovered. This plant-bed, in its extension into Yorkshire, assumes the character of a lignite or impure coal.

e'''. The Collyweston Slate is very fossiliferous in patches, the *Mollusca* being wholly marine, and mostly of the usual Inferior Oolite species. One beautiful winged *Gasteropod*, *Pterocera Bentleyi*, is tolerably abundant, although only two

* *Vide* "Notes" by Dr. Wright appended to "Oolites of Northamptonshire," *Quart. Journ. Geol. Soc.*, vol. xxvi., p. 392.

† *Ibid.*, p. 393.

‡ Owen's *Palæontology*, p. 292.

§ *Vide* Phillips' *Geology of Oxford*, pp. 196, 197; and H. Woodward, *Quart. Journ. Geol. Soc.*, 1874, vol. xxx., p. 12.

specimens have been found in the Limestone above, and it is unknown in other localities. A unique *Star-fish*, found in this slate by the Author, and named by Dr. Wright *Astropecten Cotteswoldiæ, var. Stamfordensis*, is not known to occur elsewhere.

e''''. The Lincolnshire Limestone is remarkable for a very shelly bed, called "Barnack Rag," which formerly yielded a very durable building-stone, having been quarried even by the Romans. The Formation has yielded a fine series of *Mollusca* (mostly of Inferior Oolite types, commingled with Great Oolite forms, not known to occur in so low a bed elsewhere), some remarkable *Corals* of new forms, teeth of *Fishes* and of *Teleosaurus*, patches of *Fern* (*Polypodites Lindleyi* *), and (from the Whittering "pendle") a fine single specimen of *Aroides Stutterdi* (the spadix or spike of a plant remotely allied to the *Arum* and to the "Lords and Ladies" of the hedges), which has never before been found in so old a bed.†

e''''. The most remarkable fossil of the Grey Limestone of Yorkshire is the largest form of *Belemnite* known, *B. giganteus*.

25. The *Fuller's Earth* comes in between the Inferior Oolite and the Great Oolite, but occurs only in the South-West of England.

a. It "consists of beds of brown, blue, and yellow clay, or marls, more or less compacted, of similar colours," with sometimes "thin beds of very hard brown or chocolate-

* Or, *Pecopteris polypodioides* of Lindley.

† Sharp—*Quart. Journ. Geol. Soc.*, 1873, vol. xxix., p. 274; and Carruthers, *Geol. Mag.*, 1867, p. 146, plate viii., figs. 2 and 3. See also forward, p. 101.

coloured coarse silicious sandstones, or of hard rubbly argillaceous limestone." *

b. Its greatest thickness is in Dorsetshire, where it reaches 400 feet: at the Box Tunnel, near Bath, it is 150 feet thick; throughout the Southern Cotteswolds it is less than 100 feet; it has diminished to 70 feet in the Stroud district; and thins out rapidly Eastwards, finally disappearing upon the Western border of Oxfordshire—unless, indeed, as Professor Phillips suggests, it has a feeble equivalent in a thin band of blue clay underlying the Stonesfield Slate.†

c. The Fuller's Earth has yielded about 70 species of marine *Mollusca*; of which only three are *Gasteropoda* and seven or eight *Cephalopoda*. None of its fossils are distinctive; but the greater abundance of *Ostrea acuminata* in this than in other Formations indicates that during this Period this small Oyster reached its point of culmination.

d. The Fuller's Earth Fossils, as a group, exhibit affinity both to those of the highest beds of the Inferior Oolite and to those of the lowest beds of the Great Oolite ‡—a fact suggestive of the probability that this Formation constitutes a *passage-bed* between the two.

26. The *Great Oolite.*

a. In the South-West of England, the Great Oolite consists in its lower portion of thick beds of Limestone. Some beds are famous as building-stone under the name of the "*Bath Oolite*": others contain several species of *Corals*, one

* Lycett—*Handbook of the Cotteswold Hills*, p. 86.

† *Geology of Oxford*, p. 146.

‡ Phillips—*Geology of Oxford*, p. 146.

(*Calamophyllia*) occurring in large masses, the growth of which probably occupied "many centuries." *

b. These beds alter greatly in Gloucestershire: the deep-sea deposit becomes a shallow-sea deposit, the total thickness greatly diminishes, and the strata instead of being thick-bedded are thin and laminated: they thicken again, however, in the neighbourhood of Cheltenham. They are exceedingly shelly, more than 400 species of *Mollusca* having been identified by Dr. Lycett; of which 224 species are *Gasteropoda*, and comprise no less than 50 *carnivorous* species.

c. Above the Limestones, is a Clay Formation, which assumes in some of its beds the character of an argillaceous limestone: this takes a good polish, and being rendered ornamental from the shells which it contains, it has been locally called the "*Forest Marble.*" Some beds consist of thin calcareous "tilestones," used as roofing-slates, which bear various trails and foot-prints of small *Crustacea*, etc. Similar thin laminæ, thus impressed, occur in equivalent beds in Northamptonshire.

d. In the neighbourhood of *Bradford*, Wilts, resting upon the above Formation, is a thick *Clay*, which has received the name of that town: it is characterized by the occurrence of peculiar *Crinoids* (*Apiocrinus*, "the pear-Encrinite")—remarkable as occurring in clay, although rooted in the underlying Limestone; conditions which indicate that, while yet living, these organisms were overwhelmed by argillaceous mud.

e. The Great Oolite series extends into Oxfordshire, and thence, nearly North, through Northamptonshire, East Rutland, into Lincolnshire.

* Lyell's *Student's Elements*, p. 329.

f. It is based in Oxfordshire by the *Stonesfield Slate*, an arenaceous thinly-laminated limestone (much like the Collyweston Slate described in the last Section), the organic contents of which are remarkable. The *Mollusca* and *Fishes* are marine, while several species of *Reptiles*, of the genera *Plesiosaurus*, *Teleosaurus*, *Pterodactylus*, etc., are more or less so; but these are associated with wood, Fern and Palm fronds, fruit of various *Coniferæ*, fragments of *Aroides Stutterdi*,* and other plants; also the wing-cases of Beetles, a beautiful wing of a Butterfly (never before found in so old a bed), and many other *Insects*: but, of the terrestrial remains, the most notable are those of three genera and four species of *Marsupial Mammals*, quite distinct from the *Microlestes* of the Trias and from the Rhætic genera;† and which, until the discovery of the latter, were considered to be the earliest forms of Mammalian life.

f'. These organic remains indicate that this bed was deposited at or near to the mouth of a large river. In tracing it Northwards, we find that it loses its *marine* characteristics, and assumes more and more of the character of an *estuarine* deposit: it traverses Northamptonshire, East Rutland, passes into Lincolnshire, (in which counties it has been termed by Mr. Judd the *Upper Estuarine*‡), and is probably ultimately represented by the Upper Plant Shale near Scarborough,§ a purely *fresh-water* bed, as evidenced

* *Vide* Phillips—*Geology of Oxford*, p. 173; Carruthers, *Geol. Mag.*, Ap. 1867, plate viii., figs. 2 and 3; and *ante*, page 98.

† See *ante*, pp. 87 and 89.

‡ Its *estuarine* character in these districts was first detected by Professor Morris in 1853—*vide Quart. Journ. Geol. Soc.*, vol. ix., Table II., p. 334.

§ Sharp—"Oolites of Northamptonshire," *Quart. Journ. Geol. Soc.*, 1873, vol. xxix., Table, p. 285.

by the abundant presence of the great fresh-water Mussel *Anodonta.**

f''. Near Minchinampton, some 40 miles South-West of Stonesfield, "a bed of flaggy calcareous sandstone" occurs at the base of the Great Oolite, overlying the Fuller's Earth: this bed is of purely *marine* origin, and has been considered to be equivalent to the Stonesfield Slate.†

f'''. Thus are we enabled to trace, for some 250 miles—from the shores of the German Ocean almost to the Bristol Channel—the nearly North and South and South-West course of a river of the Oolitic period, from its fresh-water condition, through its estuary, into the sea.

g. The *limestone* beds traverse Oxfordshire, become again attenuated in Northamptonshire, and finally thin-out in Lincolnshire—no equivalent being found in Yorkshire.

h. The beds in these counties are generally very rich in organic remains—more than 200 species of *Mollusca* have been identified, (including various *Cephalopoda*), and *Echinodermata*, *Crustacea*, *Fishes*, *Reptiles*, *Corals*, and *Plants*. Of these, the most noticeable are—large *Nautili*, several beautiful species of *Acrosalenia*, a small *Star-fish* (*Ophiurella*), a small *Lobster* (allied to *Eryma elegans*), numerous teeth of *Fishes* and *Crocodilia*, and a fine cone of a *pandaceous Fruit* (*Kaidacarpum Ooliticum*).‡

i. The overlying *Clay* (= *Forest Marble* and *Bradford Clay*?) is very thin and occurs only in patches in Oxfordshire, thickens again in Northamptonshire, and disappears in North Lincolnshire.

* Stated on the authority of Dr. Lycett and Mr. Hudleston.

† Dr. Lycett—"*Handbook of the Cotteswold Hills*," p. 91.

‡ Described and figured by Carruthers—*Geol. Mag.*, 1868, p. 154, and plate; see also "Oolites of Northamptonshire," *Quart. Journ. Geol. Soc.*, 1870, vol. xxvi., p. 361.

c. This Clay, in Oxfordshire, Northamptonshire, and Rutland, (probably of mixed marine and estuarine origin), has yielded remains of more than one species of a colossal land and herbivorous *Lizard*, *Ceteosaurus* ("Whale-like Lizard," a name given by Professor Owen in allusion only to its vast size). The wonderful although imperfect skeleton in the Oxford Museum, so patiently collected by Professor Phillips, is the largest known example of a saurian of any species. Its probable length exceeded 60 feet, its height at the shoulders 10 feet, and its width through the fore-part 6 feet.*

27. The *Cornbrash*.†

a. This Formation consists of a thin bed of argillaceous limestone, rarely more than about 15 feet thick: it is very rich in marine fossil remains; of which, only the *Mollusca*, *Terebratula Bentleyi*, *T. lagenalis*, *Trigonia Cassiope*, and *Chemnitzia vittata*, are sufficiently distinctive to be noted here.

b. The Cornbrash was first defined as a Geological Formation in the South-West of England. It extends (with little or no change) over nearly the whole of the Oolitic area, even into North Yorkshire, sometimes occurring in wide-spread fields, and sometimes as patches capping high lands. With regard to this fact, Jukes, in his *Manual*, remarks, "It is singular that the little insignificant-looking band called Cornbrash continues lithologically and palæontologically the same as in the South of England, while so great a change takes place in the more important beds below."

* *Vide Geology of Oxford*, pp. 247, *et seq.*

† A local name in the West of England, derived from the fact that this rock, after disintegration, makes good soil for the growth of corn.

B. The MIDDLE DIVISION comprises three Formations, the *Lower* consisting of the *Kellaways Rock*,* the *Middle* of the *Oxford Clay*, and the *Upper* of the *Coral Rag* and *Calcareous Grit*.†

28. The *Kellaways Rock* occurs in the South-West of England as an arenaceous limestone in lenticular masses, 8 or 10 feet thick, imbedded in the Oxford Clay; as a member of which it was formerly classed. In the Midland districts, however, it is always at the base of the Clay; and in Yorkshire, in the same position, it has thickened to 30 feet: moreover, of 143 species of *Mollusca* 34 only, and of 52 of *Cephalopoda* 15 only, are common both to this Formation and to the Oxford Clay. The Kellaways Rock, therefore, is now classed as a separate Formation. Its most distinctive fossils are—*Gryphœa bilobata* and *Avicula expansa*. Two beautiful *Star-fish* (*Astropecten Orion* and *A. clavæformis*—Latin, "club-shaped") have also been found in the Kellaways Rock of Yorkshire.‡

29. The *Oxford Clay* is a dense Clay, having a thickness of some 600 feet. It derives its name from its being the sub-surface Formation of the plain upon which Oxford stands: but it stretches from Weymouth in Dorsetshire to a point North of Scarborough in Yorkshire: it constitutes the sub-surface bed of nearly the whole county of Huntingdon, and sublies the alluvial beds of the great flat of the Huntingdonshire, Cambridgeshire, and Lincolnshire Fens.

* From Kellaways, in Wiltshire; where it was first observed.

† For the series of beds grouped together as the "Coral Rag" and "Calcareous Grit," the appropriate name of the *Corallian* has been suggested by Mr. Hudleston, after the French "*Corallién*" of d'Orbigny.

‡ See Dr. Wright on *Asteroidea*, in *Palæontological Society's Monographs*.

a. The fossils of this Formation are very numerous as to species, and very abundant. Of *Mollusca*, *Conchifera* and *Gasteropoda* are less plentiful than *Cephalopoda*: of *Ammonites* there are many species; some of which, in thinly laminated clays at Christian Malford, have the shell perfectly preserved; and others from the Fen beds are beautifully iridescent, from *iron-pyrites*: of *Belemnites*, one species (*hastatus*) is very elegant, and another (*Puzosianus*) is very large. At Christian Malford, some remarkable specimens of genera allied to Belemnites (*Belemniteuthis*, and a kind of *Sepia*) having the *cephalic tentacles* and the *ink-bag* still remaining, have been obtained from the Ammonite-beds.

b. The *Reptilian* remains are those of *Ichthyosaurus*, *Plesiosaurus*, and a genus allied to the *Teleosaurus*, named "*Steneosaurus*" * on account of its attenuated form: the Oxford Clay is the earliest Formation in which this reptilian genus has been found, and it is of rare occurrence.

c. It is to be noted that no Corals occur in the Oxford Clay. Masses of bituminized *wood*, or poor *jet*, are frequent.

30. The *Coral Rag* has been so called from its consisting in some of its beds in Wiltshire and Oxfordshire of *Corals*, in almost continuous reefs, in the same position as when living, and of forms which more or less resemble the existing reef-building Corals of the Pacific Ocean: it is sometimes oolitic in structure, occasionally pisolitic, often a shelly rag, and even a marly limestone.

a. The *Calcareous Grit*, with which the Coral Rag is so intercalated that the two represent one Formation only, occurs as a sand, as a sand including calcareous masses, and as a sandy limestone.

* Greek—"*stenos*," narrow.

b. The "Corallian" Group has a considerable thickness in the South-West of England, in Wiltshire, Berkshire, and Oxfordshire, and again in Yorkshire, near Scarborough; but, with the exception of a small patch at Upware, Cambs., it has been denuded away from the wide intervening area.

b'. Some Geologists have suggested that this small outlier is not a patch left by denudation, but that it* and the wider-spread Corallian beds were formed as separate Coral reefs, and represent nearly the original areas of such reefs; that the lower portion was formed in seas of the Oxford Clay Period, and the higher portion in seas of the Period of the Kimmeridge Clay †—representing in time, uniting, and being synchronous with, the later and the earlier ages respectively of the two Periods.‡

c. Besides the characteristic *Corals*, many and varied *Mollusca* (including *Ammonites* of several species, some large), numerous *Echinodermata*, and a beautiful *Star-fish*, *Astropecten rectus*, enrich these beds.

31. The *Solenhofen* or *Lithographic Limestone* of Bavaria probably interposes in time between the Coral Rag and the bed which overlies it in this country. This stone is exceedingly fine in texture: hence its use for lithographic printing.

a. Its mineral character and the conditions under which it was deposited were such as to result in the most perfect preservation of its imbedded organisms, sometimes even of portions of their most delicate structure. Sir Chas. Lyell says—"Although the number of *Testacea* (shells) is small,

* *Vide* Dr. Lycett, *Monograph of Trigonia*, *Pal. Soc.*, 1875, p. 145.

† See forward, Sec. 32, p. 108.

‡ Hudleston—*Report of Meeting of Geologists' Association at Scarborough*, July, 1875.

and *Plants* few, and these all marine, Count Münster had determined, in 1833, no less than 237 species; among them, seven species of *Pterodactyls*, six *Saurians*, three *Tortoises*, sixty species of *Fishes*, forty-six of *Crustacea*, and twenty-six of *Insects*. These Insects, among which is a *Libellula* or Dragon-fly, must have been blown [or floated] out to sea, probably from the same land to which the *Pterodactyls* and other contemporaneous air-breathers resorted."*

b. In this bed was discovered in 1862 the almost entire skeleton of a *Bird*, so preserved that even the feathers of the wings and tail are perfectly shown. This is the only instance of the fossil remains of a Bird having been found in beds older than the Cretaceous System; but it is more remarkable for the points of affinity with Reptilian forms which it exhibits in several particulars of its osseous structure: for instance, while in living Birds the tail feathers are attached to the few terminal vertebræ united or *anchylosed* together, the tail of this fossil Bird consists of no less than 20 articulated elongated vertebræ, "each of which supports a pair of quill feathers." Several species of *Pterodactylus* have such a tail, composed of similar elongated vertebræ, to which is attached, not feathers, but the posterior portion of the flying membrane. Such a *Pterodactyl* is found in the same bed as this fossil Bird, of the sub-genus *Ramphorhynchus* (Greek, "beak-bill") and the species *longicaudus* (Latin, "long-tailed"). The Bird thus found in a fossil condition was about the size of the Reok: it is in the British Museum, and has been named by Professor Owen "*Archæopteryx macrura*."†

* *Student's Elements*, p. 323.

† Greek—"*archaios*," ancient, "*pteryx*," a wing, "*makros*," long, and "*oura*," a tail.

b'. It is worthy of notice—that, as the large Dinosaurian Lizards (whose first known appearance preceded that of Birds by a considerable interval of time) presented in their osseous system marked tendencies* in the direction of subsequent Avian structure, so the earliest Birds, as here shown, were characterized by a certain affinity to Lacertian forms.

c. The UPPER DIVISION comprises the *Kimmeridge Clay*, and the *Portland Oolite* and *Sands*.†

32. The *Kimmeridge Clay* has been so called from a village on the Dorsetshire coast, in the cliffs of which it is found to have a great thickness: it gradually attenuates through Wiltshire, Oxfordshire, and Buckinghamshire, apparently thins away in Huntingdonshire and Cambridgeshire, re-appears in Lincolnshire, and has a considerable thickness in Yorkshire.

a. It is now known to occur also beneath the Weald in Sussex; in which county, it has been pierced by boring through a vertical thickness of more than 1700 feet.‡ This boring has disclosed the fact of the existence during the Kimmeridgian Period of several forms of *Crustacea* not known in other Formations;§ and it has yielded several species of *Ammonites* which had not previously been found in this country.

b. The Kimmeridge Clay has been divided by an eminent Continental Geologist‖ into the Lower, Middle, and Upper

* See *ante*, pp. 86, 97.

† See forward, "*Wealden Series*," general remarks, p. 118.

‡ See *ante*, Pt. I., Sec. 20, *b'*, p. 19.

§ *Vide* Article by Woodward, *Quart. Journ. Geol. Soc.*, 1876, vol. xxxii., Pt. I., Feb.

‖ Dr. Waagen, 1865.

Series of beds; and he has been followed by Mr. Judd * in the adoption of this classification. Mr. Blake, however, would group the beds of the Lower and Middle Series in one Division.†

c. The Lower and Middle Divisions, as represented at Ringstead Bay in Dorsetshire and at Speeton and Filey in Yorkshire, have a general thickness of from 400 to 500 feet. The Upper Division, at Kimmeridge, has a thickness of from 650 to 700 feet.‡

d. When the Kimmeridge Clay is preceded by the Coral Rag in the same section, it is based by a series of *passage-beds* of no great thickness, into which Coral Rag fossils pass up: these beds are typically developed at Weymouth, where they are about 20 feet thick.§

e. The *fauna* includes nearly 100 species of *Mollusca*: among which are—a large form of *Oyster*, *O. deltoidea*, a small one, *Exogyra virgula* (both very abundant), a large form of *Trigonia* (*clavellata*) and another (*T. Juddiana*); and of *Cephalopoda*, *Ammonites biplex*, *A. triplicatus*, *A. mutabilis*, and a curious bivalve shell-like form, called *Trigonellites*,‖ which has been considered to be either the gizzard or the bivalve operculum of a *Cephalopod*.

e'. Remains of the *Steneosaurus*, *Ichthyosaurus*, *Plesiosaurus*, *Teleosaurus*, and other *Reptiles*, are not rare; but the most remarkable are those of an immense *Saurian* called *Plio-*

* "On the Speeton Clay," *Quart. Journ. Geol. Soc.*, 1868, vol. xxiv., p. 239.

† "On the Kimmeridge Clay of England," *Quart. Journ. Geol. Soc.*, 1875, vol. xxxi., p. 197.

‡ Blake—*Quart. Journ. Geol. Soc.*, 1875, vol. xxxi., p. 200.

§ *Ibid.*, pp. 213 and 217.

‖ Greek—"*trigonon*," a triangle, and "*lithos*," a stone; on account of its triangular form.

saurus,* which seems to have had affinity, more or less, with all these forms: an idea of the size of "this old tyrant of the Upper Oolitic seas"† can be gathered from the facts that one of its quasi-crocodilian teeth measures a foot in length and three inches in diameter, and that a lower jaw is seven feet long. At Swindon, Wilts, bones of a large *Dinosaurian*,‡ a small *Ornithosaurian* § (a bird-like saurian), and a peculiar *Turtle*, have also been found in this Formation.

f. Some beds of the Kimmeridge Clay are made up of very numerous and extremely thin *laminæ*, numbering as many as 20 laminæ to one inch of thickness. The surfaces of these are covered with fossils in a compressed condition; which, although very numerous individually, are of few kinds, consisting chiefly of one *Ammonite* (*pectinatus*?), a *Brachiopod* (*Discina*), and a *Conchifer* (*Lucina*). These beds are called the "Paper Shales."‖

g. The Clay is frequently very bituminous, and sometimes contains *lignite*, which has been called "Kimmeridge Coal," and is used as fuel. This sometimes assumes the character of a poor *jet*, and as such was worked for ornamental purposes by the Romans, and perhaps by an earlier people: some round objects in this material have been miscalled "*coal money*." Some of these bituminous beds are doubtless derived from vegetable matter; but Sir Chas. Lyell has suggested that, as the fauna is entirely marine, some of the bitumen may be of animal origin.

33. The *Portland Oolite* and *Sands* derive their name

* Greek—"*pleion*," larger; the larger saurian.

† Owen—*Monograph on Pliosaurus, Pal. Soc.*, 1859, p. 15.

‡ *Ibid.*, *vide Monograph on Bothriospondylus, Pal. Soc.*, 1875.

§ Gk.—"*ornis*" (gen. "*ornithos*"), a bird.

‖ Blake, *Quart. Journ. Geol. Soc.*, 1875, vol. xxxi., p. 197.

from the Isle of Portland off the coast of Dorsetshire. The Limestone beds form the upper and the Sands the lower portion of this Formation. The former is one of the well-known building-stones of this country: St. Paul's and many other public edifices in London having been built of it.

a. The Formation occurs chiefly in the Southern counties; but the Sands are sometimes found capping the Oolitic hills as far to the North-East as Oxfordshire. At Ely, higher beds immediately overlie the Kimmeridge Clay, the Portland beds being absent; but the Formation is slightly represented near the Vale of Pickering in Yorkshire.

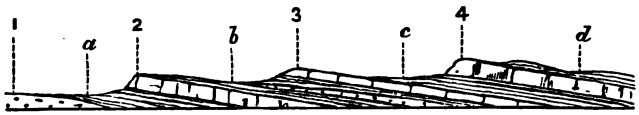
b. The Portland beds have yielded about 50 species of *Mollusca*, including the largest known *Ammonite*, "*giganteus*"; specimens of which have been found nearly five feet in diameter. In the Sands, is found a beautiful *Coral* (*Isastræa oblonga*), generally converted into *chert*—a mixed silicious often flint-like material, frequent in limestone.

General Remarks.—a. The Formations of the Oolitic System, like those of the Lias, traverse this country, from Dorsetshire to nearly the North of Yorkshire, in a belt only broken for a short space in the latter county by being overlaid by beds of the Cretaceous System. They consist alternately of beds of hard rock (mostly limestone) and beds of clay or sand; and this peculiar arrangement has had a marked influence in determining the surface contour of the wide belt of country constituting the outcrops of the Oolitic and Liassic Systems. The harder groups stand out as escarpments * facing the West and the North-West; and these

* See *ante*, Pt. I., Sec. 23, *d*, p. 21. An *escarpment*, in a large sense, is the inclined surface of the outcrop of any great Formation, such as that of the Oolite, Chalk, etc.

alternate with broad valleys formed by the softer Kimmeridge, Oxford, and Lias Clays.*

Fig. 9. Escarpments and Table-lands, alternating with Plains and Valleys—the result of the alternation of Hard and Soft Formations.



Hard Formations.	*Soft Formations.*
1. Trias.	*a.* Liassic Beds.
2. Lower Oolite Limestones.	*b.* Oxford and Kimmeridge Clays.
3. Upper Oolite Limestones.	*c.* Neocomian, Gault, and Upper Greensand.
4. Chalk.	*d.* Tertiary Beds.

b. As to the origin of the Limestone Formations of the Oolitic System, Dr. Wright has expressed his conviction that these have been derived directly or indirectly from *Coral* reefs—that even the limestone beds in which Corals themselves are not found have been formed by the deposit of calcareous pulp or mud, the product of Corals destroyed by the action of the sea.†

c. Sir Chas. Lyell has suggested,‡ as a solution of the question as to the causes of the alternation of argillaceous (clayey) and calcareous (limey) deposits during the periods of the Liassic and Oolitic Systems—that, at the commencement of the former, an argillaceous sediment, brought by oceanic currents, was being thrown down upon the bottoms of Liassic seas, unfitting them generally for the existence of *Zoophytes*; that, when from physical causes the muddy deposit ceased and the water became clear, the growth of

* See *ante*, p. 28.

† Meeting of *Cotteswold Naturalists' Field Club*, June 25, 1874.

‡ *Student's Elements*, p. 352.

stony *Zoophytes* set in, and calcareous sand formed from comminuted shells and corals, and in some cases silicious sand, replaced the clay; that clay again was deposited, to be superseded as before; and that this process was repeated as often as the alternations referred to had occurred. Such alternations must have been varied, however, by not a few changes from marine into estuarine, and even into fresh-water and dry-land, conditions, and the reverse.

34. The WEALDEN SERIES comprises the *Purbeck Beds* * and the *Wealden Beds*.

35. The *Purbeck Beds* are so called from the locality in Dorsetshire in which they are best exposed. They have an aggregate thickness of about 160 feet; are very varied in character, consisting of more or less calcareous slates, marls, and other rocks; and comprise no less than twelve distinct beds, chiefly fresh-water, but including brackish and marine deposits, and at least two land-surface beds. These have been divided into the Lower, Middle, and Upper Purbecks, each containing a distinct group of organic remains.

a. Of the Lower Purbeck, the lowest bed is a fresh-water limestone, which rests immediately upon the Portland Oolite last described. Above it, separated by an interval of six feet, are two "Dirt-beds," so called, consisting of vegetable soil, containing *in situ* the stools and roots of *Cycadaceæ*, *Zamiæ*, *Coniferæ*, etc., many of the stems of which, partially silicified, lie prostrate in the same soil. Over these are brackish-water deposits; and these are surmounted by fresh-water marls.

b. The Sub-Wealden boring in Sussex (already referred

* See forward, p. 118—*General Remarks*.

to *) has made known the presence there, in the Lower Purbeck Series, of very thick and valuable beds of *gypsum* (sulphate of lime).

c. At the base of the Middle Purbeck, is a thin bed of greenish shales, containing marine shells and plant impressions: over this, is a thin stratum of marl only two or three inches thick, which has yielded, from a very small area, (besides numerous *Insects* and air-breathing *Mollusca*), the jaws and other remains of no less than 10 genera and 25 species of insectivorous, predaceous, and herbivorous *Marsupial Mammalia*, a number exceeding that of all others found in Secondary Formations: these range from the size of a Mole to that of a small Rabbit; and one is allied to the living herbivorous Kangaroo-rat of Australia. Over this bed, are fresh-water deposits, including silicious bands filled with organic forms beautifully preserved, among them the seed of *Chara*, a genus of *water Plants* which still exists. A marine bed, containing an *Echinus* and shells of *Mollusca* of marine genera, succeeds; which passes up into limestones and shales, partly of brackish and partly of fresh-water origin, containing characteristic *Mollusca* and *Fishes* and a *Crocodilian Reptile* called "*Macrorhynchus.*" † Over this, is again a purely marine bed, then a brackish bed, and this is overlaid by a thick fresh-water bed containing shells of *Mollusca* and remains of *Fishes* and *Turtles* (*Chelonia*). The fossils of the marine beds are of Oolitic genera.

d. The Upper Purbeck is wholly of fresh-water origin, and abounds with shells of *Mollusca* and remains of *Fishes*, all of different species to those of previous beds. It is from this Division that the well-known "Purbeck Marble," so

* See *ante*, Sec. 32, *a*, page 108.

† Greek—"*makros*," long, and "*rhynchos*," a beak.

widely and so anciently used in the cathedrals and churches of this country, has been obtained: this marble is a close dark-coloured limestone, which bears a good polish, and is rendered very ornamental by its numerous shells seen in section.

e. In all these Divisions occur bands containing a very minute (almost microscopic) *Bivalve Crustacean*, called *Cypris*; each Division having its own particular species, which does not occur in the other Divisions.

f. This remarkable sequence (of fresh-water, dry land, brackish water, fresh-water, sea, fresh-water, dry land, sea, etc., in reiteration), does not so much imply a rapidity of changes in physical conditions as a great lapse of time which those changes must necessarily have involved; and this is further indicated by the several complete changes in the groups of organic forms which, by slow natural processes, were effected during the deposition of these beds.

36. The *Wealden Beds* consist of three Divisions—the lower the *Hastings Sands*, the middle the *Weald Clay*, and the upper the *Punfield Beds*.

a. The *Hastings Sands* consist of sand, sandstone, grit, clay, and shale; *clay*, in spite of the name "*Sands*," being the predominant material. The Formation occurs in Kent, Surrey, Sussex, and Dorsetshire: in the latter county, it is seen to immediately overlie the Purbeck Beds, and exhibits there some lower bands containing shells of brackish-water and marine genera. It has an aggregate thickness probably exceeding 1,000 feet: in the upper portion in Surrey, it contains thick beds of a soft sandstone, which, in the neighbourhood of Tunbridge Wells, in the form of inland cliffs, adds much to the picturesque scenery of the district.

a'. The Hastings Sands abound with the remains of *Reptiles*, including—the *Iguanodon* (so called from the teeth being like those of the largest living Lizard, the Iguana, the length of which is never more than from four to five feet) which was probably, although herbivorous, the next largest Reptile to the *Ceteosaurus*,* its length having exceeded 40 feet; the *Hylæosaurus*,† a land-Lizard, which had an enormous dorsal crest of spines, and was 25 feet in length; the *Megalosaurus*, (30 feet in length), the *Plesiosaurus*, and the *Pterodactylus*: it also contains two species of *Turtles*, several of *Fishes*, a fresh-water *Conchifer* of the genus *Unio*, and some *Ferns*.

a''. Certain beds at Potton in Bedfordshire, which contain the remains of *Iguanodon* and other Wealden forms, may be an extension Northwards of the Hastings Sands.

b. The *Weald Clay* is for the most part of fresh-water origin, "but in its highest portion contains beds of *Oysters* and other marine shells which indicate fluvio-marine conditions."‡ It attains a great thickness, exceeding 800 feet. Its most remarkable fossil remains are those of the *Iguanodon* (described above), of which between 70 and 80 distinct individuals have been identified, "varying in age and magnitude from the reptile just burst from the egg, to one the femur of which measures 24 inches in circumference."§ Bands of limestone filled with the shells of a fresh-water *Gasteropod* (*Paludina*), and which when polished is called "Sussex Marble," occur in this bed; as do numerous *Cyprides*, of distinct species to those found in the Pur-

* See *ante*, Pt. II., Sec. 26, *i'*, page 103.

† Greek—"*hylaios*," wood-frequenting; merely so called from having been found in the Weald—"*weald*" meaning a wood, see Note (*e*) Folded Table.

‡ Lyell's *Student's Elements*, p. 298. § *Ibid.*, p. 200.

beck Beds. The Weald Clay occurs in nearly the same districts as the Hastings Sands, and also in the Isle of Wight.

c. The *Punfield Beds.* This Formation was first defined, and has been described, by Mr. Judd.* It occurs in greatest thickness at Punfield in the Isle of Purbeck, and has been recognized in Sussex, the Isle of Wight, and elsewhere. It consists at Punfield of variable beds of clays and sands, the latter sometimes taking the form of ironstones, very like the ironstones of Northamptonshire: these beds are almost entirely of brackish-water origin; but they have a thin marine band at the base (21 inches thick), containing distinctive fossils, of forms which may be considered as intermediate between those of the latest Oolitic beds and those of the oldest Cretaceous beds, indicating "*passage.*" It is remarkable that a coal-bearing Formation in Eastern Spain contains the same kinds of fossils as this marine bed. The Punfield Beds have a total thickness of 230 feet.

d. At Swanage Bay (where is the finest development of the combined Wealden Series), occur:—Punfield Beds, 160 feet; Weald Clay and Hastings Sands, 2,000 feet; Purbeck Beds, 406 feet; total, 2,566 feet. If the increased thickness of the Punfield Beds at Punfield be added, the total thickness of what Mr. Judd calls the "*Wealden-Purbeck*" Series will be 2,636 feet.

e. The area of the *Wealden Series* extends West and East about 330 miles, from the Isle of Portland to near Boulogne, and North-West and South-East, from Surrey to Vassy in France, about 200 miles; or, if we extend the area to Potton, about 270 miles. Some Geologists would greatly enlarge this area on the Continent.

* *Quart. Journ. Geol. Soc.*, 1871, vol. xxvii., pp. 207–227.

General Remarks.—a. Geologists generally, because some of the marine bands contain fossils of Oolitic genera, have classed the Purbeck Beds with the Upper Division of the Oolitic System; and, because the lower beds of the Cretaceous System overlie conformably the upper beds of the Wealden Series, are of the same mineral composition, and contain a few Mollusca and Fish of Wealden genera and the remains of an Iguanodon, they have classed the Wealden Beds with the Cretaceous System.* Sir Chas. Lyell, also, has tabulated the Upper Portion of the Wealden Beds as the "Fresh-water" equivalents of the "Marine" lowest beds (*Neocomian*) of the Cretaceous System.†

b. Professor Ramsay, however, having come to the conclusion that the Purbeck Beds and the Wealden Beds are the lagoon and delta beds of one immense river, which, flowing through a continent lying to the North and West probably as large as Asia, may have rivalled in size the Ganges or Mississippi,‡ has classed them together as a "Series" intermediate between the Oolitic and Cretaceous Systems. The great aggregate thickness of the Wealden Series (2,600 feet), and its palæontological changes and physical variations, indicate an immense lapse of time; and it is not improbable that, during the deposition of the Lower and Middle Purbecks, the decadence and close of the Oolitic Period may have occurred, and that the deposition of the Wealden Beds may have witnessed the coming-in of the Period of the Cretaceous System. The Wealden Series would thus represent in time the *passage*§ of the one Period into the other,

* See Folded Table, facing p. 41.

† *Student's Elements*, p. 292.

‡ *Physical Geology*, 3d edit., p. 85.

§ See *ante*, Pt. II., Sec. 20, *b*, page 88.

and would rightly occupy the intermediate position of Professor Ramsay's classification.

b'. A consideration of the character of the successive beds of the Wealden Series will enable us to form a theoretical idea of the successive physical changes which occurred over the area associated with those beds during the immense Period of their formation—that is, during the Period which elapsed between the commencement and the ending, as to that area, of the mighty river spoken of by Professor Ramsay.

c. Towards the close of the Period of the Oolitic System, an elevation of that area commenced, and gradually but intermittently proceeded; and a fitful series of changes, from marine to lagoon or estuarine, and thence to fresh-water conditions, correspondingly took place. This elevation was accompanied by the flow, over Oolitic beds and between Oolitic shores, of that great river, and continued (being greatest probably to the North of the area, and lessening towards its Southern regions), until the channel of the river was excavated to the great depth indicated by the thickness of the subsequent fresh-water deposits.

c'. At length, elevation and excavation ceased, subsidence commenced, and with it the deposition of sediment in the river's bed: these processes went on in combination until fresh-water deposits had accumulated to the immense thickness already stated of nearly 2,000 feet. But a time came when the river channel had shallowed by its own deposits, and when the high lands of its shores had sunk to nearly the sea-level (concurrent denudation having contributed to this result): then, estuarine conditions again set in, and estuarine sediments were thrown down over the older fresh-water deposits.

c''. Ultimately, the whole area became submerged, and the deposition of the lowest beds of the Cretaceous System commenced; only, however, on what had been the dry-land surfaces of the previous time: for, subject to an occasional marine intrusion, the grand old river for ages held its own, maintained its separate identity far out to sea (as does the river Amazon at the present time), and continued to throw down its sediment within the area of its own stream; while simultaneously the ocean on either hand deposited its material. And thus perhaps it is that we find the brackish-water deposits of Punfield and of the Upper Weald side by side, as it were, and contemporaneous with, the marine deposits of Cretaceous beds.

d. The fact that incalculable ages must have passed during such changes, is in strict agreement with that of the amazing lapse of time which, for other physical and for palæontological reasons, we know must necessarily have intervened between the close of the Oolitic and the middle of the Lower Cretaceous Period.

37. The CRETACEOUS System.

The Cretaceous System is divided into the *Lower* and the *Upper*.

38. For the *Lower Division* (formerly called the "*Lower Greensand*"), the Continental term of the "*Neocomian*" has generally been adopted. Several of the lower beds of this Division (as stated in the last Section) were doubtless contemporaneous with the later beds of the Wealden Series.

The *Neocomian* group comprises several distinct series of beds, which have been classed as the Lower, Middle, and Upper, Neocomian.

At Speeton, in Yorkshire, in a series of clays, having a

total thickness of 500 feet, are exhibited the best examples of the beds of the Lower and Middle Divisions of the Neocomian group. These have been fully described by Mr. Judd.*

a. The Lower Neocomian at Speeton has a thickness of 200 feet, and has been re-divided by Mr. Judd into three zones, each marked by its distinctive *Ammonite.*

b. The Middle Neocomian at Speeton is a clay 150 feet thick: it has an equivalent in certain beds of limestone, clay, and ferruginous sands, (of a total thickness of about 70 feet), which occur at Tealby in the Lincolnshire Wolds. Three remarkable fossils characterize this Middle Division—a *Conchiferous* Shell, *Pecten cinctus*, which is nearly 12 inches in diameter; a *Cephalopod*, allied to an Ammonite, but having the whorls separated like the open coils of a flat spiral spring, and which has received the generic name of "*Crioceras*"†; and a very ornamental clawless *Crustacean* (a little larger than a shrimp), *Meyeria ornata.*

c. The upper beds at Speeton, to a thickness of 150 feet, belong to the Upper Neocomian. They are crowded with fossils: as many as 87 species of *Mollusca* (including numerous *Ammonites*, one three feet in diameter), and fine skeletons of the *Reptiles Pliosaurus* and *Teleosaurus*, have been collected from these beds. The presence of a peculiarly-formed Bivalve, *Perna Mulleti*, serves to correlate these beds with the lower beds of the Series next to be described.

d. At Atherfield Point, on the South coast of the Isle of Wight, and stretching along from Shanklin further West than the Black Gang Chine, are a series of ferruginous and other sands, clays, and indurated sands and clays, having a

* *Quart. Journ. Geol. Soc.*, 1868, vol. xxiv., pp. 220–250.

† Greek—"*crios*," a ram, and "*ceras*," a horn; like a ram's horn.

thickness of nearly 900 feet. The lowest beds contain the *Perna Mulleti* before mentioned; and this and some other fossils serve to identify those beds as equivalent to the upper beds at Speeton, and thus to continue upwards that Series, although the two localities are separated by a distance of 250 miles.

d'. Other notable fossils from the Atherfield beds are—a *Conchifer* having very peculiar curled shells, which has been named "*Diceras*" (two-horned), and some clawed *Crustaceans* like attenuated Lobsters.

d''. These beds contain also fragments and water-worn fossils from Oolitic rocks; which have doubtless been derived from the *detritus* of the denudation of the Oolitic land and shores of the great Wealden river.

e. At Folkestone, Hythe, and Maidstone, in Kent, and at localities in Wiltshire, Surrey, and Sussex, occur sands, varying in colour, which attain a total thickness exceeding 500 feet. These are also included in, and are the highest beds of, the Upper Division of the Neocomian group. In Kent, these beds are sometimes intercalated with bands of *limestone*, which is quarried as "Kentish Rag."

f. The more prominent fossils of these strata are—a *Nautilus* (*plicatus*), and another *Cephalopod*, allied to the Ammonite, but still more nearly allied to the *Crioceras* of the Middle Speeton Clay: like it, the whorls are open, but the outer one is very much enlarged, extends straight outwards as if uncurled, and is curved back at the end towards the mouth: it has been named "*Ancyloceras*," * and "*gigas*," on account of its great size.

g. The generic forms *Diceras*, *Crioceras*, and *Ancyloceras*, first appear in the Neocomian group: in which also have been found 21 species of *Ammonites*, only three of which

* Greek—"*agkylos*," curved, and "*ceras*," a horn.

occur in later beds. The total thickness of the whole group is about 1,750 feet. On the Continent, this thickness is greatly exceeded.*

39. The *Upper Division* of the Cretaceous System comprises in ascending order—the *Gault*, the *Upper Greensand*, the *Chloritic Marl*, and the three *Chalks*. There is a very complete break between the Lower and Upper Cretaceous Divisions—marked, not only palæontologically by the fact mentioned in the last paragraph, but stratigraphically, by the eroded and unconformable† surface of the uppermost Neocomian bed.‡ A considerable interval of time must have occurred between the deposition of the last-mentioned bed and that of the earliest Gault bed.

a. The *Gault* (a provincial name) attains a thickness of about 280 feet: § it consists generally of a dark blue marly clay, varied by the presence of patches and bands of green sand. It occurs in very numerous localities, cropping out upon almost every escarpment of the Chalk. The well-known "Red Chalk," which gives to the cliff-face at Hunstanton, Norfolk, so vivid an aspect, and which occurs also in Lincolnshire and near Filey in Yorkshire, is probably of the same Period as this Formation.

a'. Of the organic remains yielded by these beds, 21 species of *Ammonites* are known, eight of which are distinctive, and ten common to higher beds; also other genera of *Cephalopods*, allied to Ammonites, including *Hamites*‖ and *Scaphites*.¶

* D'Orbigny. † See *ante*, Pt. I., Sec. 27, *f*, pp. 24, 25.

‡ Judd—*Quart. Journ. Geol. Soc.*, 1871, vol. xxvii., p. 221.

§ Professor Hughes, *Geological Society*, Feb. 10, 1869.

‖ Latin—"*hamus*," a hook; hook-shaped.

¶ Latin, "*scapho*," a skiff; its form partaking somewhat of that of a boat, or rather of a canoe.

a''. The Gault fossils are remarkable for the beautiful metallic-like lustre with which they are often invested (a peculiarity sometimes also exhibited by Oxford Clay fossils): this lustre is due occasionally to the presence of metal, but more frequently to the peculiar laminated texture of the pearly shell, which decomposes the rays of light, and covers the fossils with brilliant ever-changing colours, such as those exhibited in the prismatic spectrum or in the rainbow, which are produced by similar refractive causes.

a'''. The Gault Clay is worked for bricks; which, after a particular process of burning, are of a pale yellow colour.

b. The *Upper Greensand* Formation interposes between the Gault and the Chalk in all escarpments of the last in the Southern and in some in the Midland Counties. It has a thickness exceeding 150 feet in the Isle of Wight, lessens towards the North, is still important in Buckinghamshire, but thins away in Bedfordshire: it may be present at Hunstanton in a thin band overlying the Red Chalk, distinguishable by an abundance of a ramifying *Sponge* (*Spongia paradoxica*), but it does not occur in Yorkshire.

b'. Westwardly, it increases in importance: it has a thickness of 30 feet in Dorsetshire, and appears as an important deposit at Blackdown in Devonshire. The Blackdown beds which are low down in the Formation, repose immediately upon Liassic and Triassic beds; so that the Upper Greensand Formation originally extended over and "overlapped,"* all the Neocomian, Oolitic, and Liassic beds, which have either thinned out, or (from the effects of inclination and denudation) successively cropped out, in that direction.

* When a Formation extends horizontally beyond underlying Formations so as to rest ultimately upon a still older Formation, it is said to "*overlap*" those Formations.

b''. Many of the fossils of this Formation are allied to those of the overlying Chalk. Of 156 *Mollusca* found in the Blackdown beds, 50 species are common to the Neocomian, 16 to the Gault, 20 to the overlying Chloritic Marl, and 60 are peculiar to the Upper Greensand itself. Among the distinctive fossils is a peculiar *Sponge* growing upon a stem with root-like processes, called *Siphonia* (from the Greek "*siphon*," a tube, in allusion to its being composed of a series of tubes), and *pyriformis* (from the Latin "*pyrus*," a pear), pear-shaped.

c. The question as to the Formation to which the so-called "*Coprolite Beds*" of Cambridgeshire and Bedfordshire are to be assigned, is a disputed point with some Geologists: a preponderance of opinion seems to favour the view that these beds are contained in an attenuated extension of the Upper Greensand.

c'. The phosphatic nodules which first gave the name to these beds (and the abundance of which, they being a rich manure, renders the beds so valuable) are without doubt derived from animal decomposition: many of them have been sponges, which gathered phosphatic matter, became consolidated, and were afterwards water-worn; others have had for *nuclei* Ammonites, vertebræ, teeth, etc.: of these, some have and some have not been rolled, as teeth unbroken and unworn sometimes project from the surface; and others may really be "*coprolites*," the *excreta* of Fishes and Saurians.

c''. Many of the fossils of the "Coprolite Beds" have been "*derived*"* from the denudation of the underlying Gault:

* "*Derived*" fossils are fossils which, having been originally imbedded in any Formation, have been washed out by denudation and re-deposited in more recent beds. They are generally mixed with the fossils proper of the beds in which they are found, and much care is required to recognize them

others represent Life-forms of the age of the deposit. *Reptilian* remains are very abundant, including "more than ten species of *Pterodactylus*, five or six of *Ichthyosaurus*, one of *Pliosaurus*, one of *Dinosaurus*, eight of *Chelonian*, besides other forms."* The remains of a *Bird* rather larger than a Pigeon, probably of the Gull tribe, have also been found.

c'''. In the so-called Upper Greensand of Cambridgeshire, the bones of an immense species of *Pterodactylus* have been found, which, according to Professor Owen, "had a probable expanse of wing of from 18 to 20 feet."†

d. Overlying the Greensand Formation and underlying the Lower Chalk, in the Isle of Wight, at Chardstock in Dorsetshire, and other localities, is a remarkably chalky marl bed, "full of green specks of *silicate of iron*, and called in consequence the *Chloritic Marl*."‡

d'. Its organic contents, which are very abundant, show that, as stratigraphically it divides the Upper Greensand and the Chalk, palæontologically it unites them; for, in comprising fossils common to each Formation, it represents the *passage* of the former into the latter: it contains also forms peculiar to itself, which mark it as being distinct from both.

d''. The *Cephalopoda* include a peculiar genus called *Turrilites*,§ probably first occurring in this Formation. This has a chambered shell, the numerous whorls of which have a very small radius; and these, instead of being flat like those of

as being "derived." Errors have occurred as to the identity of Formations, and as to the vertical range of genera and species, from the lack of such recognition.

* Lyell's *Student's Elements*, p. 283. † *Palæontology*, p. 274.

‡ The Rev. T. Wiltshire, in Dr. Wright's *Monograph upon Cretaceous Echinodermata*, *Palæontographical Society*, 1864.

§ Greek "*tursis*," Latin "*turris*," a tower.

the Ammonites, rise in an elevated spire like that of some Gasteropods. The mouth opening is to the left, the reverse direction of that of Gasteropods generally.

e. In some beds in Surrey, lime is intermixed with sand, forming a stone locally called "malm-rock" and "fire-stone." In the Isle of Wight, bands of limestones in this Formation contain nodules of chert.

40. The *Chalk Series* is divided into—the Lower or *Chalk Marl*, the Middle or *Chalk without Flints*, and the Upper or *Chalk with Flints.*

The *passage* upwards, from the Gault to the Upper Greensand, and from the latter, through the Chloritic Marl, to the Chalk, has been shown to be continuous.

a. Probably the oldest Formation to be included under the head of "*Chalk*" is the *Hippurite Limestone* of the South of France, which occurs also in Spain, Italy, Greece, and other countries bordering the Mediterranean. The *Hippurites* are a group of *Bivalves* which are very unlike Bivalves generally, and have no analogue in any known existing life-form. The name is derived from the Greek "*hippos*," a horse; the section of the larger valve being in plan like that of a horse's hoof. The Hippurite Limestone, in its successive beds, may have been synchronous with the highest beds of the Upper Greensand, with the Chloritic Marl, and with the lowest beds of the Chalk in this country, as examples of varieties of *Hippurites* have been found in the first and in the last of these Formations.

b. The *Chalk Marl* is the lowest member of the British Chalk series, and rests conformably upon and blends with the Chloritic Marl described in the last Section. It is an argillaceous sometimes grey soft limestone, partaking much

of the mineral character of the true Chalk, into which it gradually passes up. It occurs chiefly in the South of England, and has a thickness exceeding 200 feet. Of 32 species of *Ammonites* which its beds have yielded, 7 are peculiar to it, 11 pass up into the Chalk, and 14 have been found in older beds. Among other of its *Cephalopoda*, are *Belemnites*, *Scaphites*, and *Turrilites*.

c. The *Chalk without Flints* is several hundred feet in thickness, is not of so pure a white as the Upper Chalk, and is much indurated in parts, probably from a minute crystallization of *carbonate of lime*, the result of aqueous percolation.

c'. Its fossils are not so abundant as those of the Upper Chalk, but partake of the same general character. Of 25 species of *Ammonites*, about half are peculiar to it: a form of *Cephalopod* not found in earlier beds occurs in this Formation; it has a long straight tapering slender chambered shell, and has been called "*Baculites*," from the Latin "*baculus*," a staff. The bones of an immense *Pterodactylus*, the spread of whose wings measured from tip to tip 16 feet 6 inches (second only in size to the Upper Greensand example referred to in the last Section), have been found in beds of this Chalk in Kent.*

c''. Among the remains of *Reptiles* in this Chalk, the most remarkable are those of a genus allying the *Lacertia* (Lizards) with the *Ophidia* (Serpents). These were found many years ago in the Lower Chalk of Sussex, and have been figured and described in *Dixon's Geology of Sussex*.† The animal is there called *Dolichosaurus longicollis*‡—indicating its

* Owen's *Monograph on Cretaceous Reptilia*, *Pal. Soc.*, pt. i., pp. 88–97.

† Tables xxxviii. and xxxix., and page 388.

‡ Greek "*dolichos*," long, the long lizard, and the Latin "*longe*," long, and "*collum*," neck.

Serpent-like character. Professor Owen has described it in his Monograph on the *Reptilia of the Chalk*,* and states that it was more nearly allied to the Lizard than to the Serpent. Professor H. G. Seeley also described it at the Meeting of the British Association in 1866; and, considering that it was nearer akin to the Serpent than to the Lizard, he called it the "Lizard-serpent." But whichever extreme it may favour, it is notable as being the earliest Serpent-*like* form that is known.

d. No plane of unconformity separates the Chalk without Flints from the *Chalk with Flints*, but an intermediate bed of about 130 feet of thickness, containing a few flints only, seems to connect the two.† The *Chalk with Flints* is so distinguished from the fact that it is traversed at vertical intervals of from two to four feet by layers of *flint*, sometimes continuous and of a few inches in thickness, but more often occurring in nodular masses.

d'. The origin of Chalk Flint was for many years an unsolved problem. In the structure of many microscopic animal and vegetable organisms of the Chalk, *silex* largely occurs, and the minute *spicula* which constitute the framework of sponges are of pure silex: decomposition having released such silex, "by some chemical processes which, though guessed at, are not yet perfectly understood,"‡ it gathered about and frequently filled the interstices of sponges which grew over the sea floor during intervals of favourable conditions, and about and in other organic bodies, which are now commonly found enclosed and often

* In the *Palæontographical Society's* publications, p. 22 and table x.

† Dr. Wright's Introduction to Monograph on *Cretaceous Echinodermata Palæontological Society*, 1864.

‡ The Rev. T. G. Bonney's *Manual of Geology*, pp. 74, 109.

beautifully preserved in flint. The silex in solution required in the first instance for the formation of the microscopic organisms referred to, may have been derived from the disintegration of felspathic rocks, more than half the bulk of which is formed of silicious earth.*

d''. The organic remains in the Chalk with Flints are for the most part perfectly preserved.

Of *Mollusca, Gasteropoda* are less plentiful than *Conchifera*. The Bivalve *Inoceramus*, although not peculiar to the Cretaceous Period, is the most characteristic genus: the shell is large, very thick, and has a strong denticulated hinge. One rare species (*I. involutus*) is very peculiar, the lower valve being very large, and curved almost like the whorls of a Gasteropod,† and the upper valve comparatively flat and very small.‡

Cephalopoda are not so plentiful as in the lower beds: they consist of *Belemnites*, *Baculites*, and *Ammonites*. Of about eight species of the latter, six are peculiar to the Formation; as is also a remarkable stemless free-swimming *Crinoid*, called "*Marsupites*"—from the Latin "*marsupium*," and meaning "purse-like." *Echinodermata* are very numerous, and some species are very beautiful: one genus, *Ananchytes*,§ is very abundant, but limited to the Chalk beds. *Star-fishes*, some of elegant form, and *Crustacea*, chiefly allied to the Lobster, are not rare.

Of *Fishes*, the teeth of Sharks and the palatal teeth of

* Lyell's *Student's Elements*, p. 273.

† A specimen in flint from Glacial Gravel, at Bugbrooke, Northamptonshire, measures six inches across the volution.

‡ *Inoceramus involutus* is beautifully figured in *Dixon's Geology of Sussex*, table xxviii., fig. 22.

§ From the Greek "*Ananchitis*," a kind of gem, unrecognized.

shell-crushers are very abundant, as are the remains of other Fishes, sometimes almost in a perfect state: among the latter, one (*Beryx*) is nearly allied to the Perch.

Of *Reptiles*, Turtles (*Chelonia*), and *Ichthyosaurus*, *Plesiosaurus*, *Mosasaurus*,* and *Pterodactylus*, occur.

e. In Upper Cretaceous beds of Kansas, United States, Professor Marsh, an eminent American palæontologist, discovered, in 1872, remains of a form which, although distinctly a *Bird*, exhibited, in a series of socketed teeth in both jaws (not encased apparently in a horny sheath or beak), a marked affinity with *Reptilian* forms. It was about the size of a Pigeon, and probably carnivorous and aquatic.† Professor Marsh has given it the generic name of *Ichthyornis* ‡; and, another allied form (*Apatornis*) having been discovered, he proposes to establish a new order "*Ichthyornithes*," and a new sub-class of Birds "*Odontornithes*" § or "*Aves dentatæ*." ‖

f. White Chalk (of nearly uniform character) has been found to extend from the North of Ireland to the Crimea, a distance in a North-West and South-East line of 1,140 miles, and from Sweden to the South of Bordeaux, a distance in a North-East and South-West line of 840 miles. In Southern Russia, it attains a thickness of 600 feet, retains the same mineral characters as in this country, and includes nearly the same series of fossils. Throughout a considerable por-

* See forward, under the head of the *Maestricht Beds*, p. 132.

† Woodward—*Quart. Journ. Geol. Soc.*, 1874, vol. xxx., p. 10.

‡ Greek—"*ichthys*," a fish, and "*ornis*," a bird; a fish-bird.

§ Gk.—"*odous*" (gen. "*odontos*"), a tooth, and "*ornis*," a bird, and Latin—"*aves dentatæ*"; toothed birds.

‖ *American Journal of Science and Art*, vol. v., Feb. 1873; and *ibid.* vol. x., Nov., 1875.—*Vide*, also, *Geol. Mag.*, Feb., 1876.

tion of this vast area, the Chalk beds, by internal movements of the Earth, have been converted into a series of immense *synclinal* * curves or troughs; in three of which, respectively termed the London, the Hampshire, and the Paris "Basins," have been deposited certain Tertiary beds to be hereafter described. The intervening *anticlinals*,† to a great extent, have been wasted by denudation.

g. In the neighbourhood of *Aix la Chapelle* in Rhenish Prussia, in a Formation equivalent to the White Chalk and Chalk Marl of this country, are beds of Clay which contain fossil *Plants*, seams of *lignite*, and "perfect *coal*." The organic remains and Geological position of these strata prove that here "a gulf of the ancient Cretaceous sea was bounded by land of Devonian and Carboniferous Rocks." ‡

h. Higher than any Chalk beds in this country, are beds at *Maestricht*, on the banks of the river Meuse in Belgium, which there overlie the ordinary Chalk with Flints. These have a thickness of about 100 feet: the upper (20 feet) abound with *Corals* and *Polyzoa*, the middle (50 feet) are a soft yellow limestone, and the lowest (30 feet) pass down into White Chalk. These beds contain many Chalk *Mollusca*, comprising several genera of *Cephalopoda*, such as *Belemnites*, *Baculites*, and *Hamites*, which do not occur in any more recent beds; but with these are associated some few genera of *Gasteropoda*, such as *Voluta*, etc., which are characteristic of the Tertiary age, and are not found in any Formation earlier than these beds.

h'. As far back as the year 1766, the remains of "a gigantic marine Lizard," allied to the *Crocodilia* (but much larger than the largest existing Crocodile), was found in the

* See *ante*, Pt. I., Sec. 25, p. 23. † *Ibid.*

‡ Lyell's *Student's Elements*, 1874, p. 286.

subterranean quarries of St. Peter's Mount at Maestricht. It was fully described by Cuvier, and afterwards named by Conybeare "*Mosasaurus*," from the Meuse river. This Reptile was at least 25 feet long, and the skull nearly four feet long, the jaws being armed with a most formidable array of teeth: this skull was removed by the French Republican army in 1795 to the Garden of Plants at Paris, where it still remains. An excellent cast of the skull may be seen in the British Museum. Teeth of *Mosasaurus*, but on a smaller scale, are found rarely in the Chalk with Flints of this country.

i. At *Faxoe*, in the island of Seeland, Denmark, are yellow limestone beds, which are very similar to those at Maestricht, and also rest upon the White Chalk with Flints. One portion is composed of *Corals*, even more conspicuously than is usual in recent Coral reefs. These beds contain 30 species of *Gasteropoda* (usually rare in the White Chalk), and *Bivalves*, *Echinoderms*, *Zoophytes*, and a *Belemnite*, of species identical with those of the true Chalk: they contain, too, a *Baculite* found in the Maestricht beds, and a *Nautilus*, of a species (*Danicus*) which is found for the first time in this bed, but which occurs also in the bed next to be described.

j. In the neighbourhood of Paris, and in some other localities in France, is a *Pisolitic Limestone*, "a coarse yellowish limestone," having a thickness of about 100 feet, which occurs in patches only, and rests unconformably upon the White Chalk. Of its fossils, more than 50 species, "in their aspect," are more Eocene than Cretaceous: it also contains fossils of true Cretaceous character, some forms common to the Maestricht beds, and the *Naütilus Danicus* and other fossils of the Faxoe beds; but no Ammonites, Hamites,

Scaphites, Turrilites, Baculites, or Hippurites, so characteristic of the several British and Continental Chalk Formations, have been found in them.

k. Thus, the Palæontological evidence clearly connects, with some indications of succession, the true Chalk with the Maestricht beds, the Chalk and the Maestricht beds with the Faxoe beds, and the Faxoe beds with the Pisolitic Limestone of France.

l. The same evidence—in the presence of some *Tertiary genera* in the Maestricht beds, and in the presence of many fossils of Tertiary "aspect" and the absence of certain significant *Cephalopoda* in the Pisolitic Limestone—seems to indicate the position of these several Formations as intervening between the latest Chalk beds of this country and the oldest Formations of the great Tertiary Division which succeeds; and to exhibit a *reaching towards*, but by no means a passage into, those later Formations.

General Remarks.—a. The conclusion to which the character of the fauna of the Chalk, reasoning by analogy, would lead us is, that a warm climate prevailed over the Cretaceous area; but the warm ocean must have been traversed by icebergs, for pebbles and groups of pebbles and masses and boulders of materials of older rocks (some Palæozoic) have been found imbedded in its deposits. It had been suggested that these might have been transported in and dropped from the roots of floating trees; but Mr. Godwin-Austen has shown that their presence can only be accounted for by the fact that they were ice-borne.*

b. The material of the White Chalk is in the main nearly pure carbonate of lime. It is almost entirely made up of

* *Quart. Journ. Geol. Soc.*, 1858, vol. xiv.

various forms of animal matter; for microscopic examination demonstrates that in many beds 95 per cent. consists of the calcareous cases of *Foraminifera*,* fragments of other minute shells, and certain still more minute ova-shaped organic objects called *Coccoliths*,† *Coccospheres*,† and *Discoliths*,‡ of which the true nature has not yet been certainly ascertained; but of the silicious, some are *Diatomaceæ* and others possibly of other vegetable origin.

c. Some light has been thrown upon the probable process of the Formation of Chalk by the scientific deep-sea dredgings which have been carried on in the Atlantic for some years. The floor of the ocean, often at a depth exceeding two miles, has been found to consist of a white calcareous mud, almost entirely composed of the minute shells of *Foraminifera* of the genus *Globigerina*, mixed with the silicious shells of other microscopic forms, the silicious skeletons of the as minute somewhat paradoxical vegetable objects *Diatomaceæ*, and the *spicula* of sponges.

c'. These, in places, are not so thickly aggregated, and are then occasionally associated with an abundance of *Coccoliths* and *Coccospheres*, similar to those found as fossils in the Chalk: the last occur also at still greater depths (three miles and upwards), in a white chalky mud, containing no *Globigerina* nor any other organic remains visible to the naked eye; their presence having been detected upon microscopical examination by Mr. Etheridge. More recent deep-sea dredgings have shown that, upon the surface of "such white mud, there sometimes flourish—*Mollusca*, *Crustacea*, and *Echinodermata*, besides abundance of silicious *Sponges*;

* See *ante*, p. 45, note (*).

† Greek—"*kokkos*," any small round body.

‡ From "*diskos*," anything round and flat.

forming on the whole a marine fauna having a striking resemblance in its general character to that of the ancient Chalk." *

c''. Because of these facts, some have come to the false conclusion that the Chalk Period is still represented in the present Atlantic sediment, and that that Period has lasted on to, and indeed includes, the present time. The discoveries referred to are exceedingly instructive, being suggestive of the conditions under which our thick Chalk beds (exceeding 1,400 feet)† accumulated in the profound depths of the ocean during the long ages of the Cretaceous Period; but, although the occurrence of similar conditions in the Chalk age and in the present has naturally resulted in certain similarities in some very small forms and through a very small proportion of the faunas of the two, yet the differences between the great life-world of the one and the great life-world of the other are so essential as, on this account alone, to divide the Chalk Period from the present Period as effectively as they are separated by the immense lapse of time which has intervened between them.

d. The peculiar contours of the Chalk (in the Downs, the rounded surfaces, the coombes and valleys, the bold coast-like headlands standing out upon and overlooking the wide-spread flats of Upper Greensand and Gault), and the general features of the great Wealden area of Sussex and Kent, are the results of sub-aerial denudation—of frost, and rain, and running water.‡ The nature of the material of Chalk renders it peculiarly amenable to the dissolving action of water charged with carbonic acid, even when

* Lyell's *Student's Elements*, p. 271.

† Bristowe—Sheet 56 of *Horizontal Sections of Geological Survey*.

‡ See *ante*, Pt. I., Sec. 14, *a*, page 9.

impregnated only with the small amount which rain-water acquires in passing through the atmosphere.* By such action, "pipes" or perforations of various depths and diameters (filled with loose materials from above) have been eaten into the body of the Chalk; and by the same action, the higher Chalk surfaces have been, and are being, wasted and rounded; the lime in solution (with chalk minutely triturated) being carried away by rills and brooks and rivers: the further share of these in the work of abrasion consisting of the combined chemical and mechanical frittering out of coombes and valleys. Sub-aerial denudation is also constantly active in fashioning the physical aspects of the country, in shaping the jutting headlands, and in effecting the slow but constant recession of the varied escarpments.

e. Formerly, it was considered by eminent Geologists that the Chalk escarpments of the Wealden area had been sea-cliffs, which marked the line (and the cessation, in consequence of the elevation of the area,) of old marine denudation—a denudation which had removed the Cretaceous beds, and exposed the Wealden beds throughout their present area, measuring from twenty to forty miles from North to South, and nearly eighty miles from East to West; but Professor Ramsay has shown that this "great amphitheatre" of the Weald has been cleared of the overlying beds (many hundreds of feet in thickness) chiefly by the atmospheric agencies involved in the term "sub-aerial denudation." The whole of the remarkable phenomena connected with the inland denudation of the Chalk are thus traceable to these apparently all-inadequate agencies; the potentiality

* See *ante*, Pt. I., Sec. 28, *b*, page 26.

of which for effecting such great results could only consist with a slow but persistent action through incalculable periods of time.*

C. Tertiary Strata—Cainozoic Life Period.

General Remarks.—It has been stated that the fauna of the most recent Cretaceous age exhibits "a reaching towards" the fauna of the earliest Tertiary age:† yet the break between the two, as indicated by the utter change in animal and vegetable life, is so complete as to be without a parallel in the Earth's Geological history.

The Belemnite, the Ammonite, and allied Cephalopods having chambered shells (with the exception of the Nautilus), are wholly absent in the Tertiary seas. The great Ichthyosaurus, Plesiosaurus, Mosasaurus, Pterodactylus, and other saurians, some of which seemed in the Chalk Period to be in the very meridian of their development, have disappeared. Not a species (except some perhaps of microscopic forms), whether of Mollusc, or Cephalopod, or Fish, or Reptile, or Mammal, or Plant, of former Periods, has remained—the whole world of life has changed. A vast gulf intervenes, as yet unbridged by science—a lapse of time so great as perhaps to equal that which separates the earliest Tertiary age from our own day.‡

Of the history of this great interval, of its physical phenomena, of its life changes, we know nothing. Whole genera and families of living things may have come into

* See Ramsay's *Physical Geology of Great Britain*, chap. viii.; Whitaker on Sub-aerial Denudation, *Geol. Mag.*, 1867; and Foster and Topley on the Denudation of the Weald, *Quart. Journ. Geol. Soc.*, 1865, vol. xxi., pp. 443–474.

† See *ante*, Sec. 40, *l*, page 134..

‡ Lyell's *Student's Elements*, p. 264.

being and passed away, continents may have given place to oceans, and oceans to continents, whole ranges of mountains may have raised their lofty peaks, and again subsided into plains, during this mighty hiatus which human knowledge has failed to fill.

Geological research, however, may yet, in some region of the Earth, discover Formations and explore strata representing this lost time, and supply the links that are here wanting in the chain and "*continuity*" of the World's life-history.*

This chasm aptly separates the "*Secondary*" from the "*Tertiary*" Division of Strata, and the "*Mesozoic*" from the "*Cainozoic*" Life Period.

41. The EOCENE System is divided into the *Lower*, the *Middle*, and the *Upper* Eocene.

42. The *Lower Eocene* consists of—

a. The *Thanet Sands* (so called by Professor Prestwich from their being well exposed in the Isle of Thanet) are the lowest beds of the Eocene group in this country, no Formation intervening between them and the White Chalk. They occur also in the Northern part of Kent, on the sea-coast between Herne Bay and the Reculvers. Their greatest

* Since the above was written, certain beds in Woodpecker Bay, New Zealand, have been described by Dr. Hector (Director of the Geological Survey of that country) as being possibly *passage-beds* between the Cretaceous System and the Eocene and later Tertiary Formations. These he has designated as the "*Cretaceo-Tertiary Series*"; and they may possibly supply (as I have above suggested), although slenderly, the desiderated continuity.

These beds have been found to contain fossils of decidedly Cretaceous types (such as *Saurian* bones, *Inocerami*, etc.), associated with Tertiary forms (*Nautilus ziczac*, &c.), and with the remains of a gigantic *Penguin* and of a *Turtle*. These last "indicate a *fauna* not unlike that at present existing in the vicinity."—*Vide Quart. Journ. Geol. Soc.*, 1876, vol. xxxii., Pt. I., Feb., pp. 53, *et seq.*

thickness is about 90 feet, and they contain some marine *Mollusca* peculiar to them; such as, *Aporrhais** *Sowerbyi* and *Scalaria*† *Bowerbankii* (*Gasteropoda*), *Cyprina Morrisii* and *Pholadomya cuneata* (*Conchifera*), etc.

a'. Near Beauvais, in the North of France, are marine sands (called the *Sables de Bracheux*) which coincide in age with the Thanet Sands: in them has been found the skull of a quadruped allied to a Bear, which has received the name *Arctocyon primævus* (from the Greek "*arktos*," a bear, "*kyon*," a dog, and the Latin "*primævus*," primeval); and this is the oldest Eocene Mammal yet discovered.

b. The *Woolwich and Reading Series* (formerly called the *Plastic Clay*, having been used for pottery purposes) occurs in the places named and at Blackheath in the "London Basin,"‡ in the Isle of Wight and near Bognor in the "Hampshire Basin,"‡ and at Newhaven in Sussex. The shells obtained from these beds indicate a varying and alternating succession of fresh-water, estuarine, and marine conditions.

b'. Remains of a *Pachydermatous* § *Animal*, allied to the Tapir, have been found in the Plastic Clay near London. This animal is the *earliest large Mammal* known to have occurred in this country, having been "double the size of the American Tapir." It has been called by Professor Owen *Coryphodon* (peak-tooth), on account of the character of its dentition.‖

* *Aporrhais*, spout-shell, a name adopted by Aristotle in the fourth century B.C., from the Greek "*aporrheo*," to flow away.

† From the Latin "*scalaris*," like a ladder.

‡ See *ante*, Sec. 40, *f*, p. 132.

§ Greek—"*pachys*," thick, and "*derma*," skin; thick-skinned—animals such as the Elephant, Rhinoceros, &c.; or hoofed animals, such as the horse.

‖ *History of British Fossil Mammals*, p. 299, figs. 103, 104; *Palæontology*, pp. 356–358.

b''. Two fresh-water or estuarine shells, *Cyrena cuneiformis* and *Melania inquinata*, occur in these beds, and are also common in the equivalent *Argile Plastique* near Paris; in which also have been found bones of a gigantic bird (*Gastornis Parisiensis*) "as large as an Ostrich, but more robust, and with affinities to wading and aquatic birds." *

c. The *London Clay* consists of brown and bluish grey clay, and attains a thickness of 500 feet. It occurs at Highgate, passes under the London area, reaches its greatest thickness in the Island of Sheppey at the mouth of the Thames, and is found near Harwich in Suffolk, and near Bognor in Sussex.

c'. The lower portion, to a thickness of some 450 feet, is entirely of marine origin, as shown by the *Mollusca*: these number 266 species, of which 160 species are peculiar to the Formation. About 5 per cent. are of existing species; and these are the earliest forms (not microscopic) which identify the past with the existing fauna. Six species of *Nautilus* are found in these beds; but none occur in later Formations (nor in the existing seas) of the British area.

c''. The upper 50 feet at Sheppey represent estuarine deposits or those of the delta of an important river. They abound with *Tree* and other *Plant* remains, having affinity with genera now existing in Australia, the Philippine Islands, and Southern India.

In these beds, have been found—the teeth and bones of *Crocodiles* and large *Turtles* †; a *Serpent* of Boa-constrictor affinity, 12 feet in length, (*Palæophis*, old-snake, being the

* Owen's *Palæontology*, p. 328.

† "More species of true Turtles have left their remains in the London Clay at the mouth of the Thames, than are now known to exist in the whole world; and all the Eocene *Chelones* are extinct."—Owen's *Palæontology*, p. 317.

earliest true Serpent yet discovered)*; the remains of *Quadrupeds* of genera also now first appearing, including—an *Opossum*, an animal of the porcine tribe (*Chœropotamus*, river-hog) with tusks like ordinary canines,† a large beast (*Hyracotherium*) remotely allied to the Rhinoceros, a kind of *Tapir* (*Lophiodon*, crest-tooth),‡ the still larger animal of the same family *Coryphodon*,§ and a small animal (also a Tapiroid) the *Pliolophus*,‖ which was so named by Owen on account of a dentition not characterizing any later species of Mammals, but indicating marked affinities to the dentition of the Marsupialia of the Lower Oolites,¶ and so far connecting the older and the later Mammalian faunas.

c'''. It is to be observed that, of the *Mammalia* of these early Tertiary Formations, by far the greater number are nearly allied to the *Tapiridæ*, river-frequenting animals, now living chiefly in South America, but also in Sumatra, Malacca, and Borneo.

c''''. Besides these fossils, are the bones of a gigantic *Bird* of the *Ostrich* tribe (*Dasornis*** *Londinensis*), as large probably as the extinct Madagascar Bird, *Æpyornis maximus* (the greatest tall bird), the eggs of which are from 12 to 14 inches in diameter. An "*Ornitholite*" (bird-stone), however, is the most remarkable of the whole series of organic remains which this Formation has yielded, "on account of the

* *Vide* Owen's Monograph (Palæontographical Society), "*Reptilia of the London Clay, Ophidia*," pp. 56, 63.

† Only now represented by the *Peccaries* of South America.

‡ Owen's *Palæontology*, p. 364.

§ Described on page 140.

‖ Greek—"*pleion*," more, and "*lophos*," a crest; more crested—indicating the dental affinity as above stated.

¶ *Palæontology*, pp. 346 and 358.—*Vide* forward, "*Conclusion*," p. 187.

** Gk.—"*dasys*," downy, and "*ornis*," a bird; a downy bird.

transitional character which it manifests to the *Pterosaurian** order," of which the *Pterodactylus* is the typical genus: this is the skull, about six inches long, of a true bird, having mandibles furnished with unsocketed "bony tooth-like processes," ten on each side of both upper and lower mandibles. Professor Owen concludes that the living animal "was a warm-blooded feathered biped, with wings, and further that it was web-footed and a fish-eater, and that in the catching of its slippery prey it was assisted by this *Pterosauroid* armature of its jaws." Professor Owen has named this *sauroid Bird* "*Odontopteryx*"—from the Greek "*odous*," a tooth, and "*pteryx*," a wing.†

d. In France, the *Soissonnais Sands* (according to the opinions of Sir Chas. Lyell and Professor Prestwich, based upon the consideration of about 300 species of *Mollusca* which they have yielded, of which only about 33 species are identical with those in the London Clay,) interpose in date between the latter and the oldest beds of the Middle Eocene group in England. The London Clay is not represented in France, or only partially so by these beds.

43. The *Middle Eocene* consists of—

a. The *Bagshot Sands*, a series of variously coloured marine sands and clays of considerable thickness, which occur South of London, in the locality from which they derive their name, in isolated patches or "outliers" as left by denudation. They are almost unfossiliferous.

b. At *Alum Bay* in the Isle of Wight, and near Bournemouth in Hampshire, are sands which are probably the

* Winged Lizard.

† See Paper on a "Dentigerous Bird" in *Quart. Journ. Geol. Soc.*, 1873, vol. xxx., p. 511, with plates.—See also the Cretaceous "*Ichthyornis*," *ante*, Sec. 40, *e*, p. 131.

equivalents of the lower portion of the Bagshot Sands. Some white clay bands in these sands abound with remains of *Plants*, sometimes beautifully preserved: as many as 40 species have been identified; and these, in the main, are allied to types occurring in the flora of Australia and sub-tropical India. Shells of the *Unio* are evidence that these alternating bands are of fresh-water origin.

c. In *Bracklesham Bay*, on the Eastern part of the Hampshire coast, are green clayey sands which have been recognized as equivalent to the middle portion of the Bagshot Series. These are rich in marine *Mollusca*, the general character of which points to a tropical or sub-tropical climate. Mr. Etheridge has shown that as many as 393 species have been obtained; of which, 240 are peculiar to the Formation, 70 common to the older London Clay, and 100 to the newer overlying beds. Of *Conchifera*, the large *Cardita planicosta* is common to both Bagshot and Bracklesham; and of *Gasteropoda*, the huge *Cerithium giganteum* occurs also in corresponding French beds, reaching sometimes to a length of two feet.

c'. Among other fossils from Bracklesham, are—bones of two species of *Serpents* of the genus *Palæophis** (allied to that from the Sheppey beds, see page 141), one of which, 20 feet in length, Professor Owen has concluded was a *Sea-serpent*; *Crocodiles*, of the genus *Gavialis*; and *Fishes*, including four genera of *Sharks*, etc.

d. In the equivalent *Calcaire Grossier* of the Paris Basin, besides *Mollusca* to the number of 400 species, nearly identical with those of the English beds, there have been found the remains of *Fishes* and *Reptiles*, and the bones of the

* *Vide* Owen's Monograph (Palæontographical Society), "*Reptilia of the London Clay, Ophidia*," pp. 56–63.

Mammalia, *Palæotherium* ("old wild beast") and *Lophiodon* ("crest-tooth"), both of which were Tapir-like animals.

e. The *Lower Calcaire Grossier* and the underlying *Soissonnais Sands* * are characterized by an abundance of a small *Foraminiferal* shell of the genus *Nummulites* (so called from the Latin "*nummus*," money, its form being round and flat like a piece of money). *Nummulites* also sparingly occur in some higher Eocene Formations.

f. The greatest point of interest presented by the *Middle Eocene* group is—that a Formation coeval with these *Nummulitic* beds, and called the "*Nummulitic Limestone*," is the thickest, the most widely spread, and probably the most significant, of all the grand series of Formations which range between the close of the great Primary Division and the present time. This Formation occurs in the Swiss Alps at a height of 10,000 feet above the sea-level, and has there a thickness of several thousand feet; it also occurs in the Pyrenees, in Algeria, in Morocco, in Egypt (where at the same time it supplied a natural foundation and the stone for building the Pyramids), and in Palestine (where it caps the Chalk Formations of the Mount of Olives); it is traceable through Asia Minor,† across Persia to the mouths of the Indus, in the mountain ranges to the North-West of the Indian peninsula, in Bengal, and in China; and it has been found in Western Thibet, at a height of 16,500 feet above the level of the sea.

f'. It is clear, as Sir Chas. Lyell says,‡ that the great mountain chains of the Alps, Pyrenees, Carpathians, and

* See *ante*, Pt. II., Sec. 41, *d*, p. 143.

† Many of the ancient Grecian temples were built of it, and it supplied some of the marble for Greek statuary.

‡ *Student's Elements*, p. 261.

Himalayas, "into the composition of whose central and loftiest parts the *Nummulitic* strata enter bodily," could have had no existence until after this Period, during which the sea flowed where these chains now rise; for the Nummulites found as fossils in their central and highest rocks "were unquestionably inhabitants of salt-water."

f''. The conditions of the ocean bottoms in which the Nummulitic sedimentary deposits were formed, were doubtless analogous to those of the Chalk sea-bottoms, and to those of the bottom of the Atlantic at the present time.*

f'''. But, before the formation of these great mountain ranges, and before the very sediment of which they were composed had been deposited in ocean depths, the area of this country had been inhabited by "various quadrupeds, by herbivorous pachyderms, by insectivorous Bats, and by Opossums."†

g. At *Monte Bolca*, near Verona, North Italy, are beds of fissile limestone, intermingled with a series of submarine volcanic deposits: these contain well-known species of *Nummulites*, and are thus shown to be of Middle Eocene date. They abound with marine *Fishes* beautifully preserved, as many as 133 species having been described by Agassiz.

h. In North America, nearly upon the same Geological horizon, occur beds similar to, and probably the equivalents of, the *Nummulitic Limestone* of the Old World. They contain Eocene fossils, and the remains of numerous individuals of an immense marine mammiferous animal, a *carnivorous Whale*, which reached a length exceeding 70 feet, and to which Professor Owen has given the name of

* See *ante*, Pt. II., *General Remarks*, *b* and *c*, pp. 134–136.

† Lyell's *Student's Elements*, p. 262.

Zeuglodon ("yoke-tooth") on account of its dental peculiarities.*

44. The *Upper Eocene.*

a. In the Isle of Wight, and at some points on the opposite mainland of Hampshire, occur certain Sands overlying a thick Clay, which some Geologists would hesitate in separating from the Bagshot and Bracklesham beds. At *Barton Cliff*, near Lymington, Hants, the Clay attains a thickness of nearly 300 feet, and abounds in marine shells, for the most part beautifully preserved. Of 321 species of these, not more than 140 are common to the Bracklesham beds; a sufficient palæontological reason for distinguishing the Formations, although there may be no absolute stratigraphical break.

b. The *Headon Series*, deriving its name from Headon Hill, Isle of Wight, occurs also at Whitecliff and Alum Bay in the same Island, and at Hordwell near Lymington. The top and bottom beds are of fresh-water origin, while the intermediate beds are in part estuarine and in part marine; the latter, at Brockenhurst, containing many beautiful *Corals.*

b'. Among the *Mollusca*, a minute *land-shell* (*Helix labyrinthica*) is remarkable as occurring in a living state only in America.

b''. Seven species of *Turtles*, an *Alligator*, a *Crocodile*, two species of *Land Snakes*, and *heterocercal Fishes* of the genus *Lepidosteus* (the existing *Bony Pike* of the American lakes and rivers)† have been found in the lower portion of this Series at Hordwell Cliff.‡

* *Palæontology*, p. 377. † See *ante*, Pt. II., Sec. 11, *c''*, p. 63.
‡ Lyell's *Student's Elements*, p. 239.

b'''. These beds have also yielded numerous extinct *amphibious* and *partially amphibious* or river-haunting *Mammalia*, including :—

Of True Tapiroids—

The *Palæotherium* and *Lophiodon*, which occur in earlier Formations.

The *Hyopotamus* (river hog)* and the *Microchœrus* (little pig),† which occur for the first time in these beds.

Of Transitional Genera—

The *Anoplotherium* (unarmed wild beast), "a lighter and more elegant form" of Tapiroid than the Palæotherium,‡ and presenting some foreshadowing rudimentary characteristics of the *Ruminantia*.§

The *Dichobune* and *Dichodon*, genera allied to the Anoplotherium, but showing successively increasing *ruminantian* affinities.‖

(Neither of these has been found in earlier Formations.)

b''''. From Hordwell have also been obtained the remains of a small *Insectivorous* animal, the *Spalacodon* (mole-tooth),¶ previously unknown; and a *Carnivorous Mammal*, the *Hyænodon* (Hyæna-toothed), "more fell and deadly than modern Wolves and Tigers,"** but chiefly remarkable as being probably the earliest large *carnivorous* animal yet known among British fossils.††

* Owen's *Palæontology*, p. 400.—Greek—"*hys*," a pig, and "*potamos*," a river.

† *London Geological Journal*, Pt. II., 1846, page 5; *Mag. of Natural History*, vol. xiv., 1844, p. 350.—Gk.—"*micros*," little, and "*choiros*," a pig.

‡ Owen's *Palæontology*, p. 367.

§ Animals which chew the cud, such as the Ox, Deer, &c.

‖ Owen's *Palæontology*, pp. 368 and 371.

¶ *London Geological Journal*, Pt. II., 1847, p. 6; *Mag. of Natural History*, vol. xiv., 1844, p. 350.—Gk.—"*spalax*" (gen. "*spalacos*"), a mole, and "*odous*," a tooth.

** Owen's *Palæontology*, p. 372.

†† Lyell's *Student's Elements*, 1874, p. 239.

c. The *Osborne* or *St. Helen's Series* (the localities in which it occurs being indicated by its names) is of fresh-water and estuarine origin, and its beds are very variable in character and thickness. Near Ryde, a freestone is obtained from it, which is much used for building purposes: it is called the Nettlestone Grit.

d. The three Formations last described have equivalents in *French* beds; but these present no peculiarities requiring particular notice.

e. The *Bembridge Series* occurs near Yarmouth and at other places in the Isle of Wight. It consists of a series of marl, clay, and limestone beds, of fresh-water, estuarine, and marine origin; and it contains organic remains in accordance with these several conditions. In them have been found the remains of *Turtles*, and of *Mammalia*: the latter comprise no less than six species of *Palæotherium*, one of *Chœropotamus*, two species of *Anoplotherium*, and one of *Dichobune*—all previously referred to.

f. The Upper Beds of the Upper Eocene are represented in France by the remarkable *Gypsum Series of Montmartre*, which has acquired a world-wide fame, not only as the source of the manufacture of Plaster of Paris, but as the deposits whence were obtained the rich series of remains of *Mammalia*, *Birds*, *Reptiles*, and *Fishes*, in the study, classification, and description of which, the great Cuvier, in the early days of modern Geology, added so much to the world's knowledge and to his own renown.

g. The *Mammalia* of these beds consist of upwards of 50 species, a great majority of which were of Tapiroid genera, such as *Palæotherium* and *Anoplotherium* and *Xiphodon* * *gracile*: the last was about the size of a Chamois, and, as

* From the Greek "*xiphos*," a sword—sword-toothed.

Cuvier inferred from its skeleton, "as light, graceful, and agile as the Gazelle." There have also been found—the remains of a few *Carnivorous* animals, including *Hyœnodon* [see page 148], a *Dog* (*Canis Parisiensis*), and a *Weasel*; those of a *Squirrel*, an *Opossum*, and a *Bat*; remains of about 17 species of *Birds*, and of numerous species of *Reptiles* and *Fishes*: none of these being referable to existing forms. "The tribe of land quadrupeds most abundant in this Formation is such as now inhabits alluvial plains and marshes, and the banks of rivers and lakes—a class most exposed to suffer by river inundations," * and most likely, therefore, to be entombed in river and lake deposits.

45. The MIOCENE System is divided into the *Lower* and *Upper* Miocene.

46. The *Lower Miocene* is very scantily represented in this country:—

a. The *Hempstead Beds*, in the Isle of Wight, which have a thickness of about 170 feet, and consist of several alternating series of fresh-water and estuarine sands and marls, succeeded above by marine sands and clays. These beds are by some Geologists classed with the Upper Eocene because the *fauna* agrees with the *fauna* of that Division, and by others with the Lower Miocene because the *flora* is of that Period. They are probably *passage* beds, and represent a period of transition between the two.

a'. These beds contain the remains of *Mammalia*, in genera akin to, although in species distinct from, those of the Bembridge Beds. Remains of *heterocercal* fresh-water *Fishes*, of

* Lyell's *Student's Elements*, p. 255.

the same genus (*Lepidosteus*) as those occurring at Hordwell, are found at Hempstead.

a''. The thick lignite deposits at *Bovey Tracey*, near Exeter, and *Plant* beds alternating with volcanic deposits in the Scotch *Isle of Mull*, comprise all the Formations in this country that are certainly assignable to this period. The *flora* of these indicates the existence of a sub-tropical climate.

b. Lower Miocene Formations occur in many parts of Europe, of a very variable character, and to a very great thickness. They occur in Switzerland to a thickness of several thousand feet, and at a height of from 5,000 to 7,000 feet above the sea-level. These are for the most part of fresh-water origin, although some are certainly brackish-water deposits, and a still smaller proportion marine.

c. Many of the *Mammalia* of which the remains have been found in these beds are nearly allied in genera to Mammalia of the Upper Eocene age; and they comprise in addition—two hornless species of *Rhinoceros*, two small *ruminants* (*Microtherium*, a "small beast," and *Dorcatherium*, a "deer-beast"); a small rodent (*Titanomys*), the precursor of the Horse (*Hipparion*, "little horse"), and a formidable carnivorous animal as large as a Lion (*Machærodus*, "sabre-tooth"); all of which appear for the first time in these beds. Besides these, there are the teeth of *Sharks* and other *Fishes*, including those of the immense Shark *Carcharodon*.

d. The *flora* of the European Lower Miocene is very abundant, and is particularly remarkable from the significant fact that a considerable number of its genera are very closely allied to existing American forms. Its general character indicates a sub-tropical climate.

e. In the Croatian Province of Hungary, are beds of this age, which contain, in a hard marlstone, more than 200 species of fossil *Plants*, and a very rich *Insect fauna*, including 10 species of *White Ants*, some of gigantic size, large *Dragonflies*, and *Grasshoppers*, *Beetles*, and *Butterflies*: of the wings of one example of the last, not only is the colour retained, but the pattern also, so as to have enabled Professor Heer to correlate it with the species *Vanessa Hadena* of India.

f. In several localities in the Rhine districts of Germany are peculiar *Plant* deposits, not so hard frequently as ordinary lignite, but which, because of their usual colour, have been called the *Brown Coal.* These beds frequently contain *leaves* and the remains of *Fishes*, *Insects*, etc., well preserved.

g. Fossil *Plants* of the Lower Miocene age have been obtained from the *Arctic Regions*—from Iceland, Spitzbergen, and Greenland, as far North as the 70th degree of latitude—amounting to 194 species; of which no less than 137 species are from Greenland, one-half being of trees, although there are no trees now growing in Greenland. One-third of the number of species are identical with the species of the Lower Miocene of Central Europe, and all point to the prevalence even in those regions of a warm climate.*

h. In the regions of the Upper Missouri in North America, fresh-water beds of the Lower Miocene contain bones of land and fresh-water *Chelonians* and of extinct *Quadrupeds*; many of the same genera as those of the equivalent beds in Europe, but some differing in species. Of the last, are a huge *Tapiroid* (larger than any known earlier species, and

* See *ante*, Pt. I., Sec. 38, p. 37—*Changes of Climate over large Areas.*

called *Titanotherium*), a *Ruminant* allied to a form found in Miocene beds in the Siwâlik Hills in India, and a species of the great carnivorous *Machœrodus* already mentioned.

47. The *Upper Miocene* is not represented in this country, except that perhaps the "derived" * *Mammalian* remains of the Crag Formations † are relics of an Upper Miocene land which occupied an area including probably that of the present German Ocean.

a. It is largely developed on the Continent—in France, in Belgium, the Rhine districts, in Switzerland, in the Vienna Basin, in Italy, and in Greece: it is also found in India, and in the United States.

a'. The deposits in the Valley of the Loire called the "Faluns" (a French agricultural term), which Sir Chas. Lyell selected as typical Upper Miocene beds, consist of shelly sand and marl, and are lithologically much like the Coralline Crag of Suffolk.‡ Similar beds occur in Brittany, in the country South of Tours, near Bordeaux, in the country about Toulouse, and in several districts in the South of France; also in Belgium, and in Italy in the range of hills which includes the well-known Superga near Turin.

a''. These beds consist variously of marine, estuarine, and fresh-water deposits. Of rather more than 300 species of *Mollusca* obtained from them, as many as 72 are identical with existing species.

a'''. In *Mammalia*, a great advance as to the number and character of species, compared with the mammalia of older Formations, is observable. In addition to some previously existing *Tapiroids*, we have the immense animal

* See *ante*, Note (*), page 125.

† See forward, Sec. 49, *b''*, III., page 162, *et seq.*

‡ See forward, Sec. 49, page 159, *et seq.*

(first made known by Cuvier as the "*Tapir gigantesque*") the *Dinotherium* ("huge beast"): the length of a skull in the British Museum (*i. e.* between its posterior and anterior extremities) is 3 feet 8 inches, and from its lower jaw, deflected downwards and backwards, project two immense tusks. The *Hippopotamus* (river-horse), *Rhinoceros*, and a very large and peculiar variety of Elephant, the *Mastodon* * (the teeth of which being very unlike those of subsequent Elephants, are perhaps intermediate between those of Tapiroids and those of Elephants), now first appear; as do several species of *Deer*, a kind of *Giraffe* (*Helladotherium*, "Greek beast," having been first found in beds of this age near Athens), and several species of *Apes* and *Monkeys*; and, of marine mammalia, the *Dolphin*, the *Walrus*, and a species of the *Manatidæ* or Sea-cows. Bones and teeth of the great carnivorous feline animal *Machærodus* also occur in these deposits.

b. The Upper Miocene beds of the *Vienna Basin* consist of sands, conglomerates, limestones, and clays. Of their *Mollusca*, no less than 500 species of *Gasteropoda* have been described, of which one-fifth are identical with species living in the Mediterranean, African, and Indian Seas; but the proportion of existing to extinct species of *Conchifera* is greater than this.

b'. Of *Mammalia*, have been found *Dinotherium*, *Mastodon*, *Rhinoceros*, *Acerotherium* ("hornless Rhinoceros"), and *Hippotherium* ("horse-beast") or *Hipparion* ("little horse"), a link between the Horse and some forms of the Tapiroids, and the foreshadowing type (perhaps the progenitor) of the existing Horse.

c. These remains are all found in corresponding beds at

* Greek—"*mastos*," a nipple, and "*odous*," a tooth.

Eppelsheim in Hesse Darmstadt, together with "the bones of a large *ape* of the *Gibbon* tribe, the most Northerly example yet discovered of a *Quadrumanous* animal."

d. Beds of the same period near *Athens* have yielded—remains of *Dinotherium*, *Mastodon*, *Hipparion*, two species of *Helladotherium* (a *Giraffe*), *Antelope*, and other mammalia, some living and some extinct, together with those of *Rodents* akin to the Marmot and Beaver, an *Ape* allied to living species, a *Carnivorous animal* intermediate between the Hyæna and the Civet, and a *Ruminant* between the Antelope and the Goat.

e. The Upper Miocene Beds of *Switzerland* have been called "the *Molasse*," from the French word "*mol*," because of the *soft* nature of their material. They occupy the country between the Northern portion of the Jura range and the Alps. The Group is divided into the *Lower*, a *marine* series of beds,* which correspond with the "*Faluns*" of France, and the *Upper*, *fresh-water*, which are best shown at *Œningen*, in the valley of the Rhine between Constance and Schaffhausen.

e'. The *marine* deposits of the Upper Miocene beds of the "Molasse" occur at a height of 2,470 feet above the sea. Their *Mollusca* agree in the main with the Mollusca of the French "*Faluns*": about 90 species of *Plants* occur in these beds, although almost entirely absent in other corresponding beds of the Continent.

e''. The *fresh-water* beds of *Œningen* consist of a series of marls and limestones (often finely laminated, and formed apparently by very slow deposition), and abound in remains (frequently beautifully preserved) of *Fishes*, *Insects*, and *Plants*, with a few characteristic *Mammalia* and *Reptiles*:

* Overlying Lower Miocene beds, alluded to, *ante*, Sec. 46, *b*, p. 151.

these organic remains have chiefly been derived from two quarries, situated respectively at 550 feet and 700 feet above the level of the neighbouring Lake of Constance.

e'''. Professor Heer of Basle has identified more than 500 species of *Plants* and upwards of 800* species of *Insects* from these beds, which he considers to have been formed in a lake, to which these Plants and Insects, together with other remains, were brought down by some considerable river, and imbedded in a kind of travertine formed at the bottom by calcareous matter supplied in solution by springs.

e''''. The *Mammalia* include—a peculiar form of *Mastodon* (*Tapiroides*, "Tapir-like"), an animal allied to and about the size of a *Fox* (*Galecynus*† *Œningensis*), an extinct kind of tailless *Hare*, and a ruminant, *Palæomeryx*, etc. The *Reptilia* include an aquatic *Salamander* (larger even than its great living representative the Salamander of Japan), and numerous *Tortoises*. The *Fishes* include the *Pike*, the *Tench*, the *Roach*, and a multitude of small species.

f. In the *Siwâlik Hills of India*, which lie at the Southern foot of the great Himalayan chain, an important series of deposits (discovered and investigated by the late Dr. Falconer and Sir Proby Cautley) answer to the Upper Miocene beds of Europe. They consist of marls and sandstones, and contain a great variety of fossil *Mammalia* and *Reptiles*, and about 15 species of *fresh-water Testacea*: of the last, 11 are extinct, and four still live in Indian rivers.

f'. The *Mammalia* include some genera peculiar to these deposits, and many genera which occur in European beds

* The entire list of Swiss species of Insects from the Lower and Upper Miocene together numbers 1,322. Professor Heer has examined 5,080 specimens from Œningen alone.

† "Weasel-Dog." Discovered in 1829 by Sir Roderick Murchison, and deposited in the Museum of the Geological Society.

of the same age: they comprise—*Hippotherium* (or *Hipparion**); several *Tapiroids*, *Hexaprotodon* ("six front teeth"),† an extinct *Hippopotamus*,‡ two species of *Mastodon*, two of *Elephas* § (the earliest occurrence of this genus), three other *Elephantine Proboscidians* intermediate between *Mastodon* and *Elephas* (of the sub-genus *Stegodon* ‖ of Dr. Falconer), an animal (*Chalicotherium* ¶) intermediate between the *Rhinoceros* and *Anoplotherium*, and two species of *Hog*; of true *Ruminantia*, the *Giraffe*, *Antelope*, *Stag*, *Camel* (the earliest known), and a remarkable gigantic new form, the *Sivatherium* (the Indian god "Siva's beast"), a four-horned animal, allied to the Prongbuck of North America **; of *carnivora*, *Machœrodus*, *Hyœna*, a *sub-Ursine* animal (*Hyœnarctos*, "Hyœna-Bear"), and a large genus allied to the *Otter*; and a *Monkey*.

f''. Of *Reptilia*, have been found in the same bed—several *Crocodiles* of huge dimensions (one still existing in the Ganges), another *Saurian* still living in India, and a colossal *Tortoise* (*Colossochelys Atlas*), the shell of which was 12 feet 8 inches long and 8 feet in breadth, the entire length of the animal having been about 18 feet, and its height 7 feet. A large *Ostrich* was associated with the other remains.

* Owen's *Palœontology*, p. 397.

† *Ibid.*, page 400.

‡ Greek—"*hippos*," a horse, and "*potamos*," a river.

§ *Elephas hysudricus* and *E. planifrons* of Falconer.—*Quart. Journ. Geol. Soc.*, 1865, vol. xxi., pp. 266 and 275.

‖ Gk.—"*stego*," covered, protected, "*odous*," a tooth.

¶ Gk.—"*chalix*" (gen. "*chalikos*"), gravel; from the bed in which the remains have been found.

** Described and figured in *Falconer's Palœontological Memoirs and Notes* by Dr. C. Murchison, 1868, vol. i., pp. 247–279; also in an instructive article by Dr. J. Murie (with plates of the restored animal), in *Geological Magazine*, vol. viii. (1871), pp. 438–448.

f'''. Numerous fossils of the Siwâlik type have been found in *Perim Island* in the Gulf of Cambay (Western India), and with them a *Dinotherium*, clearly identifying the deposit with the Upper Miocene of Europe.

g. In *North America*—in North Carolina, Maryland, Virginia, and Delaware—occur strata of the age of the Upper Miocene of Europe and of the earlier beds of the English Crag, and combining the two, as shown by characteristic *Molluscan genera*; which include a very peculiar *Gasteropod*, the *Fusus quadricostatus* of Maryland. Many of these genera are still living, but are confined to the New World, to the Western side of the Atlantic.

48. The PLIOCENE System—

Is mainly represented in this country by beds which occur in Essex, Suffolk, and Norfolk; and which have received the provincial name of "*The Crag*." The System is divided into the *Older Pliocene* and the *Newer Pliocene*.

49. The *Older Pliocene* includes the *White* or *Coralline Crag* and the *Red Crag*.

It was stated in the last Section that certain strata in the Eastern districts of the United States agree in some of their fossil forms severally with the Upper Miocene beds of the Continent and with the oldest Crag beds of this country. In the neighbourhood of Antwerp, there are strata which underlie, and are therefore older than, beds of the same age as the Red and Coralline Crags of our Eastern Counties, but which rank vertically above the Miocene Series: they are called the "*Black Crag*" or "*Diestein*." These American and Belgian strata may therefore, in combination, represent a *passage* time uniting the Miocene and Crag Periods.

a. The *White* or *Coralline Crag* (or such of it as was left after a denudation which preceded the deposition of the Red Crag) has a very limited horizontal range, being only found in the county of Suffolk. It has a gross thickness variously estimated at 83 feet* and 60 feet.† Professor Prestwich has estimated the depth of the sea in which these beds were deposited at from 500 to 1000 feet;‡ Messrs. Searles Wood, jun., and Harmer at less than 300 feet.

The Formation has been termed the "*White*" Crag because of the absence of the ferruginous stain which characterizes the Red Crag, and the "*Coralline*" Crag because of the *Corallines* (really *Polyzoa*) with which its middle portion abounds.

a'. The number of species of *marine Testacea* which the Coralline Crag has yielded (after eliminating "derived"§ and doubtful species) amounts to 391; of which 142 (or 36 per cent.) are extinct,‖ and 249 (or 64 per cent.) existing¶: a proportion indicating a nearer approach than in the latest beds of the Miocene System to the Molluscan fauna of the Recent Period.

a''. The lowest bed of the Formation contains *phosphatic nodules*,** which, in all probability, had an origin in animal

* Professor Prestwich—*Journ. of Geol. Soc.*, 1871, p. 120.

† Messrs. Searles Wood, jun., and F. W. Harmer—*Introductory Outline, Supplement to Crag Mollusca, Palæont. Soc.*, 1874, page ii.

‡ *Journal of Geol. Soc.*, 1871, p. 135.

§ "Derived" fossils (as stated at page 125) are fossils which have been washed out of their original beds by denudation, and re-deposited in beds of subsequent formation.

‖ The word "extinct" in this instance, and whenever used in reference to the Crag beds, is to be understood as meaning, *not known as living.*

¶ Searles Wood—*Supplement to Crag Mollusca, Palæontological Society*, 1874, p. 219. These numbers do not quite agree with those given by Professor Prestwich in paper previously cited, p. 128.

** Professor Prestwich—*Journ. Geol. Soc.*, 1871, pp. 119–121, 125, 133.

matter; also numerous "derived" fossils of *Terrestrial* and *Marine Mammals*, etc., of the same character as, but less numerous than, those found in similar beds in the Red Crag, to be described in the next Section. These remains, with little doubt, are for the greater part originally of the *Miocene* age, although some (such as seven vertebræ of a Whale found connected) are certainly those of animals which lived in the Coralline Crag Period. The presence of a large transported boulder of porphyry in this lowest bed is an evidence that icebergs traversed the seas of this age.*

b. The *Red Crag* (so called on account of its deep red or ochreous colour, due to the presence of the oxide or rust of iron) consists in some places of numerous thin *laminæ* of sand and shells, generally very much inclined (or "*false-bedded*"), the effects of strong currents and water-action during deposition, and perhaps of foreshore sub-aerial or tidal conditions of accumulation. Its total thickness does not greatly exceed 25 feet. It occurs chiefly in Suffolk and in Essex, and has a much wider spread than the Coralline Crag (which it sometimes encircles and "overlaps"), covering an area of about 300 square miles.

b'. After eliminating 87 "derived" species, the marine shells of the Red Crag number 248; of which 69 (or about 27 per cent.) are extinct, and 179 (or 73 per cent.) are recent.† The *Molluscan fauna* includes a great abundance of a reversed form of the existing Whelk (*Trophon antiquus*, var. *contrarius*), the whorls turning from left to right, and which preceded the dextral form of modern seas: the sinistral form is still found in a living state, although rarely. Another very characteristic *Gasteropod* is the *Voluta Lam-*

* Professor Prestwich—*Journ. of Geol. Soc.*, 1871, p. 117.

† Lyell's *Student's Elements*, p. 183.

berti; which occurs first in the Miocene marine beds of the Continent, but is not found in any beds later than those of the Crag.

b''. The *Phosphatic Bed* at the base of the Red Crag is of more important development than that of the Coralline Crag. Its thickness varies from 6 to 18 inches, and the nodules and organic remains frequently contain as much as 60 per cent. of phosphate of lime, and are valuable as manure.

The *organic remains* of the Phosphatic Bed (other than those of Mollusca, Corals, &c.) may be divided into four classes*:—

I. Those which (as indicated by their condition) are of the age of the deposit, such as—*Mastodon Arvernensis*, *Elephas meridionalis* (which now first appears, and which was probably the largest species of the whole tribe), teeth of *Horse* and of some *Ruminants*, and the bones, etc. of *Cetacea*.

II. Those which have been "derived" from the Coralline Crag, and in greater number from somewhat older beds equivalent to the Belgian Black Crag or Diestein, including —*Hipparion*, *Mastodon Borsoni*, vertebræ and ear-bones of *Whales* (*Balænodon gibbosus*, etc.), a *carnivorous Whale* (*Squalodon*), a genus allied to the *Sperm Whale*, *Porpoises*, *Dolphins*, and other *Cetacea*, teeth and vertebræ of a colossal *Shark* (*Carcharodon*)† and of other Sharks, etc.

* This classification is only provisional, as great uncertainty at present invests the whole question: it is certain, however, that of these remains the great bulk is of an origin foreign to the bed in which they are found.—*Vide*—Lankester, *Quart. Journ. Geol. Soc.*, 1870, vol. xxvi., pp. 495–499; Prestwich, *ibid.*, 1871, vol. xxvii., pp. 346–349; S. Wood, jun., and Harmer, *Supplement to Monograph on Crag Mollusca*, *Pal. Soc.*, 1874, p. xii.

† A tooth in the possession of the Author represents a triangle of which

III. Those which have been "derived" from *Miocene* beds, including—*Mastodon Borsoni*, *Rhinoceros Schleiermacheri*, *Tapir priscus*,* *Hipparion*, *Hog*, several species of *Deer*, a *Canine* or *Feline* animal (?), *Beaver*, a marine *Mammal* of the genus *Halitherium*, tusks of *Walrus* (some of immense size), numerous teeth of *Seals* of various species, including one now represented by the *Manatus* ("Sea-cow"), *Fishes*, etc.

IV. Those which have been "derived" from the Eocene (London Clay), of which may be mentioned—teeth of several genera of *Tapiroid Mammalia* (*Hyracotherium*, *Coryphodon*, etc.), teeth of *Crocodilia* and of *Sharks*, remains of other *Fishes*, *Turtles*, and *Crabs*, *Wood* (sub-tropical?) sometimes beautifully silicified, etc.

b'''. Organic remains of older beds, such as the Chalk and Lias, and included masses of Coralline Crag, also occur, indicating great denudation, sometimes combined with ice-action, during the Red Crag period.

b''''. Much ice-borne material, including unrolled blocks of flint, some measuring 2 feet by 18 inches, in this lower bed, indicates the frequency of icebergs at any rate in the early Red Crag Seas; and there are data in higher deposits which justify the supposition of icebergs having stranded on the shores of a little later time.

c. In *Italy*, at the foot of the Apennines, both on the Adriatic and Mediterranean sides, are Tertiary strata forming a line of low hills between the older chain and the sea. These are chiefly composed of strata equivalent to our Coral-

the base measures $5\frac{8}{10}$ inches, and each side $6\frac{8}{10}$ inches: this is rather larger than a tooth in the Hunterian Museum, London; which Professor Owen, upon a comparison with teeth of existing Sharks, has concluded must have belonged to a Shark 60 feet in length!—*Palæontology*, p. 132.

* The *Tapir* is now only known as living in America and Eastern Asia.

line and Red Crags, the Mollusca to a considerable extent agreeing therewith: but overlying these, are beds, probably agreeing with our Newer Pliocene; while the lowest beds are perhaps scarcely more recent than the Miocene age. Certain beds in the Upper Val d'Arno,* to be hereafter described,† are probably also of the Crag period.

50. The *Newer Pliocene* consists of the *Norwich* or *Fluvio-Marine* Beds and the *Chillesford* and *equivalent* beds.

a. The *Norwich Crag* takes its name from its occurring in its greatest development in the neighbourhood of that city. It consists of incoherent sand, loam, and gravel, and contains shells, in the main marine, but including as many as 20 fresh-water and land species. Its beds must have accumulated at or near to the mouth of a river, or on an area subject to the influences of tidal and river-current alternations: hence, they are also called the "*Fluvio-Marine*" beds.

a'. "An entire skeleton of *Mastodon* is said to have been discovered in these beds (at Horstead, Norfolk) some years since,"‡ the latest bed (unless the "stone bed," see next page, be later) in which the remains of *Mastodon* have been found.

a''. The marine *Mollusca* consist of 111 species, of which 18 (nearly 17 per cent.) are extinct, and 93 (or more than 83 per cent.) existing.§

a'''. These beds occur in patches resting upon the White Chalk with Flints, and seldom exceed an aggregate thickness of twenty feet. The eroded surface of the Chalk is often

* Lyell's *Student's Elements*, p. 189.

† See forward, p. 165.

‡ Prestwich—*Journal of Geol. Soc.*, 1871, p. 459.

§ Searles Wood's *Supplement, Palæontological Society*, p. 219.

profusely bored by the bivalve *Pholas crispata* of the Crag Seas,* the shell frequently remaining in the crypt. The species is identical with the living one.

a''''. "At their junction with the Chalk, there invariably intervenes a bed called the 'Stone-bed,' composed of unrolled chalk-flints," † mingled with the remains of *Mastodon Arvernensis* (its last appearance ‡), *Elephas meridionalis*, two extinct species of *Deer*, etc. It is to be noted that no phosphatic nodules occur in this bed, and that, whereas the similar beds in the Coralline and Red Crags contained "derived" fossils of the Miocene and Eocene ages respectively, the Mammalian remains of the Norwich bed are wholly of Pliocene species, including (besides some forms previously enumerated as occurring in older beds)—*Bear*, *Hyœna*, a *Feline* animal allied to the *Leopard*, *Horse*, *Ox*, *Trogontherium* ("gnawing beast," akin to a very large Beaver), *Otter*, *Water-Rat*, *Field-Mouse*, and *Birds* §: some of these forms have been found for the first time in these beds. The early discovery therein of Mammalian remains led to the Norwich Crag being formerly called by Mr. Charlesworth the "*Mammaliferous Crag*."

b. The *Chillesford* and *equivalent Beds* have a much greater horizontal extent than the Norwich Crag: they occur not only at Chillesford between Woodbridge and Aldborough in Suffolk, but in Norfolk (in some Sections in which county they are seen to overlie the Norwich Crag), and in many other localities; and occasionally they "overlap" older Crag beds. They reach a thickness of 20 feet, and consist of layers of sands and laminated clays, all very micaceous.

* Prestwich—*Journal of Geol. Soc.*, 1871, p. 460.

† Lyell's *Student's Elements*, p. 174. ‡ See last page.

§ Professor Prestwich—*Journal of Geol. Soc.*, 1871, p. 456.

b'. These beds are of varying marine and fluvio-marine (or *quasi*-estuarine) character. The skeleton of a *Whale* has been found in the upper bed. Of 87 species of marine *Testacea*, 14 (or 16 per cent.) are not known as living, and 73 (or 84 per cent.) are still existing.*

c. About 10 miles above *Florence*, a part of the valley of the river Arno, which is narrow and deep, is called the Upper Val d'Arno, and was probably a lake at the time that the valley below Florence was an arm of the sea. The deposits in the area of this lake reach a thickness of some 750 feet; of which, the lower 550 feet, consisting of dark clay with layers of lignite, are of the Older Pliocene age. The rich *flora* of these beds has no parallel in the Pliocene Formations of this country: it indicates a climate somewhat colder than, and a period immediately following, that of the Miocene period. The upper 200 feet are of Newer Pliocene age, and contain *Mammalian* remains of the same general character as those of the Norwich Crag and Norfolk Forest Bed.†

d. In *Sicily*, the Newer Pliocene deposits occur in greater development than in any other part of Europe. They cover nearly half the Island, reach an aggregate thickness of 2,000 feet, and in the centre of the Island an elevation exceeding 3,000 feet. "Since the accumulation of these beds, the whole cone of Etna (11,000 feet in height, and 90 miles in circumference at its base) has been slowly built up,"‡ an operation involving the lapse of very many thousands of years. The *Mammalian* remains agree with the Geological era of the beds. The *Molluscan* remains are chiefly remarkable for their beautiful preservation: many species

* Searles Wood's *Supplement to Crag Mollusca*, p. 219.

† See forward, pp. 168–171. ‡ Lyell's *Student's Elements*, p. 186.

are still living in the adjacent seas; although, as it would appear, these species are really older than the Island itself.

e. In newer Tertiary deposits of *North America*, the remains of a *Mastodon* occur, the teeth of which partake of the form of the teeth of *Dinotherium*.

f. In Pliocene deposits in *Piedmont*, the skeleton of a *Mastodon* has been found, the teeth of which are intermediate between those of the American form and the common species *Arvernensis*.

General Remarks.—a. A comparison of the numbers of species of *Marine Mollusca* of the several British Crag Formations * will show—that, of 391 species in the Coralline Crag, 36 per cent. are extinct; of 248 species of the Red Crag, 27 per cent. are extinct; of 111 species of the Norwich Crag, 17 per cent. are extinct; and of 87 species of the Chillesford Beds, 16 per cent. are extinct—indicating a gradual but marked approach in identity of species to the Mollusca of existing seas.

a'. The general character of the *Mollusca* of each of these Crag Periods, and their progressive changes, have a further significance. The Mollusca of the Coralline Crag have a very noticeable affinity to the living Mollusca of the Mediterranean, indicating nearly similar climate and conditions: but a gradual departure from such a similarity is observable in each successive Formation (and even between the upper and lower portions of a Formation), until, in the Chillesford Beds, comparatively few species having Mediterranean affinities remain, and a climate is indicated probably not very different from that of this country at the present time.

* See *ante*, Pt. II., pp. 158–165.

b. There is some variation of opinion as to the identification and classification of the English Crags and some subsequent Formations:—

b'. Professor Prestwich considers that the Norwich Crag is synchronous with the Red Crag, and that the lithological and other differences are only of local origin; also that the Chillesford beds, wherever situated, are simply an upper and deeper-sea member of the same Formation.*

b''. Mr. Searles Wood is of opinion that, while there is a complete separation of the Coralline and Red Crags, "the Red and Fluvio-marine Crags, and their overlying Chillesford clay and sand, can be regarded as only one deposit, constituting in England the Upper Crag, as the Coralline does the lower; and that the triple division of the Crag, which has for so many years been assumed, must be abandoned." †

b'''. Biding the settlement of disputed points, I have adopted the arrangement in my text, subject to any future needed modifications.

D. Quaternary or Post-Tertiary Strata— Cainozoic Life Period (*continued*).

51. The Post-Pliocene or Pleistocene System.

a. With this System, great changes were inaugurated: the *fauna* became more assimilated to that of the Human era, and towards the close of its Period *Man* himself appeared; whilst the *flora* differed little from the indigenous flora of the Recent age.

* *Journal of Geol. Soc.*, 1871, pp. 453–461.

† *Supplement to Crag Mollusca, Pal. Soc.*, p. 198.

b. The System is marked by the intervention of a great Glacial epoch, which affected more or less the whole area of this country and the greater part of the Northern Hemisphere, materially altering the surface contour and the relative disposition of land and water.

c. This Glacial epoch led the late Professor Phillips to classify the Post-Pliocene Formations as — *Pre-Glacial*, *Glacial*, and *Post-Glacial*.*

52. The *Pre-Glacial* period is most importantly represented in this country by Formations exposed in the cliffs and upon the shores of the Northern coasts of Norfolk; which there immediately underlie thick deposits of the earliest phase of the Glacial Period. These Formations, in ascending order, are distinguishable as †:—

a. The *Weybourne Sands*, a marine deposit.

b. The *Forest Bed*, which consists of two distinct portions—the lower, a land-surface bed; and the upper (sometimes called the "Elephant Bed"), an Estuarine deposit.

c. The *Westleton Sands* and *Shingle* ‡—for the most part marine.

a'. The Weybourne Sands (which near Cromer adjoin laterally the Forest Bed, underlie the Estuarine portion of the same, repose upon the Chalk, and in such position have been called the "Iron Pan," being ferruginous) have been considered by Professor Prestwich to be equivalent to the Norwich Crag,§ while Mr. Searles Wood calls them the

* See his Work on "*The Rivers, Mountains, and Sea-coast of Yorkshire*," 1853; and *Guide to Geology*, 5th edition, 1864, p. 147.

† Lyell's *Antiquity of Man*, 4th edition, 1873, p. 260.

‡ Professor Prestwich—*Journal of Geol. Soc.*, 1871, p. 461.

§ *Ibid.*, pp. 459–60.

"Lower Glacial Sand." * Sir Chas. Lyell † says that these Sands are closely allied to the Norwich Crag and Chillesford Beds, but are distinguished by the presence of the *Conchifer Tellina Balthica*; which now first appears, but occurs in profusion in all subsequent Formations down to the Recent period: on which account, he has concluded that these Sands are nearly coeval with the Land Forest Bed, but slightly newer, Elephants' teeth having been found in them. The *Mollusca* generally vary little from the Mollusca of existing seas, including only three species not known as living.

b'. In the lower, the land-surface, portion of the Forest Bed, are the remains of an actual forest. At the base of the cliff near Cromer, stretching for 40 miles along the shore, and a considerable way under the sea, is a bed in which occur numerous upright stumps of *Trees*, some of them two to three feet in diameter, with their roots spreading out horizontally in the same position as when they were growing (as they did grow) upon the very site upon which they are now found. This forest must have existed through a long period of time; as is indicated by the size of the tree stumps which remain, and by the vast accumulation of vegetable matter about and above them.

The *Trees* and other *Plants* of which the remains have been found in these beds are of kinds familiarly growing in this country at the present time, viz.:—the *Scotch* and *Spruce Firs*, *Yew*, *Oak*, *Alder*, *Birch*, common *Sloe* or *Black-thorn*, *Buckbean*, *Osmunda Regalis* (*Fern*), *Hornwort*, *White* and *Yellow Water Lily*, *Pondweed*, etc. The *Mollusca* consist wholly of fresh-water and land shells of existing species.

* *Supplement to Crag Mollusca, Pal. Soc.*, p. 151.

† *Antiquity of Man*, 1873, p. 259.

The *Mammalia* of which remains have been found in earlier Formations and which again occur in these beds are * :—

Machærodus (sabre-tooth).
Elephas meridionalis.†
Rhinoceros Etruscus.†
Hippopotamus.
Horse.
Hog.
Ursus Arvernensis.†
Trogontherium (an immense Beaver).†
Beaver.
Shrew-Mouse.
Water-Rat.

Those which appear for the first time in these beds :—

Elephas antiquus.‡
„ *primigenius.*‡
Rhinoceros megarhinus.
Bos primigenius.
Cave Bear.
Wolf.
Fox.
Musk-Rat.
Mole.
Cervus megaceros (great horned —gigantic Irish Deer.
„ *Polignacus.*†
„ *Sedgwickii.*†
„ *carnutorum.*†
„ *verticornis.*†
Red Deer.
Roebuck.

b''. The overlying Estuarine bed consists of variable clays and sands, interspersed by layers and patches of plant-remains ; which afford evidence that its formation, under altered conditions, immediately followed that of the bed beneath it.

The Estuarine bed contains the remains of a *Walrus*,

* This list is taken from Lyell's *Antiquity of Man*, 1873, p. 257—supplied by Professor Boyd Dawkins.

† Not found in later beds.

‡ Of these two Elephants, *E. antiquus* was the larger, although not so large as *E. meridionalis*. *E. primigenius* was larger than any living species. *E. antiquus* had long straight tusks, *E. primigenius* curved tusks. The remains of Elephants are very common in this country: about 1812, an Oyster-bed was discovered off Happisburgh, within the range of the Forest Bed on the Norfolk coast, from off which the fishermen brought up in their dredges in about 14 years as many as 2,000 Elephant molars, representing some 400 animals.

Narwhal (or Sea-Unicorn), *Whales* of various species, and several *Fishes*.

c'. The Westleton Sands and Shingle* attain a thickness of from 30 to 40 feet. Near Cromer, they interpose as a thin band between the Estuarine portion of the Forest Bed and the lowest Glacial "Till"; but inland, where the Forest Bed and Weybourne Sands are wanting, they reach their maximum thickness, and immediately overlie the Chillesford Beds. It is a question, indeed, whether they are not identical with the Weybourne Sands, and whether the beds thus differently named are not really earlier and later portions of one Formation, divided locally by the intercalation of the Estuarine deposits.†

General Remarks.—The lowest of these Formations of the Post-Pliocene Pre-Glacial age represents a land the surface conditions of which were much the same as those of the present day, with perhaps a somewhat milder climate. The trees and plants are familiar to us, although the animals are strange. Then flourished the largest Elephant the world has ever seen. The sea gently washed the shores of that forest land, and for a time all was luxuriance and peace. At length, a slow subsidence took place, and the area of the forest became the area of an estuary. A colder climate gradually set in, glaciers descended from the high lands, and the woolly-coated Elephant for the first time appeared. Age after age passed, and then the ocean engulphed the whole. Again a long lapse of time, succeeded by Glacial

* The "Bure Valley Beds" and "Pebbly Sands" of Messrs. Searles Wood, jun., and Harmer—see Note to *Introduction to Supplement to Crag Mollusca, Pal. Soc.*, 1872–4, page xv.

† *Vide* Lyell's *Antiquity of Man*, 1873, 4th edit., pp. 259–261, fig. 32.

elevation and Greenlandic ice-conditions, next to be described; resulting in the deposition of the overlying Glacial Clays and "Contorted Drift" of the Norfolk cliffs.

53. The *Glacial Period* was characterized upon the area of this country by *three* remarkable series of changes and phenomena, and may be divided into eras as follows:—

a. The first era—during which a considerable elevation occurred, accompanied by an extreme arctic climate.

b. The second era—during which there was a great subsidence, the area of the depression being occupied by a stormy ocean, studded with ice-islands, and traversed by icebergs.

c. The third era—during which a commensurate elevation and emergence took place, a return to terrestrial conditions, the latest appearance of glaciers in this country, and a gradual modification of climate.

a'. The amount of elevation during the first era has not been ascertained; but it is known that the mountains of Westmoreland, Wales, Scotland, and Ireland, were much higher than they are now, and that many of what at this time are only hills were then mountains.

a''. The climate was so severe, that all valleys were filled with glaciers, the mountains and lowlands alike covered with ice, and the whole area of this country and the greater part of Europe enveloped in one great almost unbroken ice-sheet:* this ice was in a state of slow but constant motion, and was continually carving out and grinding away the rock-surfaces beneath; so that valleys were deepened, and in some instances excavated, by this agency, and often

* See *ante*, Pt. I., Sec. 38, pp. 37, *et seq.*—*Changes of Climate over large Areas.*

immense lake-basins were scooped out by the action of ice alone.*

Vast accumulations of mud (studded with fragmentary masses of rock) and gravel were the result of this great ice-action; and hence probably have been derived the older and sometimes separated portions of the Boulder Clay.

This period of extreme cold has left its indications in numerous *Moraines*, "on a scale so immense that the largest now forming in the Alps are of mere pigmy size when compared with them."† These are found often at great distances from existing glaciers, and occur "in the Altai Mountains, the Himalayas, the Caucasus, the Rocky Mountains, the Andes, in New Zealand, the Sierra Nevada and the Pyrenees of Spain, the mountains of Morocco, the mountains of Sweden and Norway, the Black Forest and the Vosges, and in many Northern Mountain chains or clusters."†

b'. The era of elevation and arctic glaciation was succeeded by an era of great subsidence, probably of 2,300 feet.‡ This subsidence occurred over the British area (with the exception of a small Southern portion), and over a great part of Central Europe, extending Eastwards into Russia, and North and South from the Northern shores of the Baltic nearly to the Alps.

b''. The area of subsidence was occupied by an ocean, studded with islands covered with snow and glaciers, rendered turbid by the ice-mud of the previous age, and traversed by icebergs, the ruins of ancient glaciers, § laden with rock-masses, gravel, sand, and mud: these, as the ice-

* Professor Ramsay—*Journal of Geol. Soc.*, 1862, p. 185; and "*Physical Geology of Great Britain*," 1872, pp. 168–177.

† Ramsay—"*Phys. Geol. Gt. Brit.*," 1872, pp. 147–150.

‡ Ramsay, *Journ. Geol. Soc.*, 1852, p. 372.

§ See *ante*, Pt. I., Sec. 14, *c''*, p. 13.

bergs melted, were strewn along the sea-bottom; and hence were formed the more recent portions of the Boulder Clay and Glacial Drifts and Gravels, which once covered nearly the whole surface of the country North of the Thames, patches still commonly capping the high grounds of many inland districts, and which occur over wide-spread areas in Scotland.

b'''. The *Mollusca* of the Glacial deposits are not numerous, but comprise upwards of 30 species now found only in Arctic Seas: among them are—*Astarte Borealis*, *Cyprina Islandica*, *Leda Arctica*, *Pecten Islandicus*, *Saxicava rugosa*, *Scalaria Greenlandica*, etc. An upper bed of the Glacial series occurs at *Bridlington* in Yorkshire, which has yielded about 60 species of Mollusca, about one-third being Arctic: of the whole number, only three species are not known and two doubtfully known as living.

c'. On to the third era the Arctic conditions continued, but became gradually modified during the slow elevation and emergence of the subsided area. Glaciers occupied the valleys of mountainous regions; but diminished by degrees, and ultimately disappeared. The land-surface again teemed with vegetation; and mammalian life-forms migrated in abundance from the Continent, as yet unseparated from Britain.

Remarks.—These series of phenomena (of elevation, depression, and re-elevation) during the Glacial period, followed as they were, after intervals, by the separation of Ireland from Great Britain, and Great Britain from the Continent, fashioned and left the general surface contour of this country much as it is now: yet important physical changes have since occurred—mountains and hills have

been wasted, some valleys have been excavated and others enlarged and deepened, thick fluviatile deposits have accumulated and have been subsequently channeled by existing streams, rivers in some instances have ceased to flow and the courses of others have been altered, whilst coast lines have greatly changed.

[NOTE.—Sir Chas. Lyell has included the Pre-Glacial Formations and the Glacial Formations of Norfolk and Bridlington in the Newer Pliocene System and in the Tertiary Division.* Mr. Searles Wood would abandon the Post-Tertiary Division altogether, and include all Formations between the Norwich Crag and the Recent Period in the Tertiary Division.† I have followed the older classification of Professor Phillips,‡ Sir Charles Lyell,§ and others.]

54. The *Post-Glacial* Period.

a. The great characteristic of this Period is, that, so far as we are at present assured, it witnessed the *commencement of the Human Era.*‖ While all its *Mollusca* are of existing species, the *Mammalian* remains represent many animals of extinct kinds: these remains are stratigraphically associated with the works and the remains of *Man*; indicating that such extinct animals had lived contemporaneously with him.

b. The remains of extinct animals which have been found

* Table of Strata, *Student's Elements*, 1874, p 109.

† *Supplement to Crag Mollusca, Pal. Soc.*, p. 201.

‡ *Guide to Geology*, 5th edition, 1864, p. 147.

§ *Elements of Geology*, 1865.

‖ Mr. James Geikie, in his recent work on the "*Great Ice Age*," would assign an *Inter-Glacial* position to the earliest known Human Period; and the discovery of a human *fibula* in the Victoria Cave near Settle in Yorkshire, in a deposit overlain by an *apparently* Glacial clay, has been regarded by some as conclusive evidence that Man lived in this country prior to the last Inter-Glacial period: but Mr. Evans in his *Presidential Address* at the Anniversary Meeting of the Geological Society of 1875, after alluding to these views, stated his opinion that present *data* are insufficient to enable us to carry back the Human Era into Pre-Glacial times.

in this Country and on the Continent associated with the works and the remains of Man are as follows* :—

Machærodus latidens—Sabre-toothed Lion.
Felis leo, var. *spelæa*—Cave Lion.
Hyæna spelæa—Cave Hyæna.
Ursus spelæus—Cave Bear.
Elephas antiquus—Ancient Elephant.
„ *primigenius*—Elephant of the first kind ("Mammoth," or Woolly Elephant).†
Rhinoceros tichorhinus—a Woolly-coated Rhinoceros.‡

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* Lyell's *Antiquity of Man*, 1873; and Professor Boyd Dawkins—*Journ. of Geol. Soc.*, 1872, pp. 410–445; and *Cave Hunting*, 1874, pp. 360–1.

† A carcase of *Elephas primigenius*, which had been perfectly preserved by the ice, was exposed upon the fall of a frozen cliff at the mouth of the Lena in Siberia in 1799. Wolves devoured the flesh, but the skeleton and a fragment of the hide are in the Imperial Museum at St. Petersburgh. The hide was covered with coarse hair, forming a shaggy mane about the neck: under the hair was a woolly coat, eminently adapted for protection against cold. Another entire Mammoth, having tusks 8 feet in length, was found in a half-frozen condition in the Russian river Indigirka in 1846; as graphically described by Benkendorf—see notice by Professor Boyd Dawkins in *Popular Science Review*, July 1868. The tusks of these animals are abundant in Northern Russia, and so preserved by the ice as to retain their quality as good ivory: they form an important article of commerce with this country. A head of *E. primigenius* in the British Museum, found in 1864 at Ilford in Essex, is adorned with tusks 10 feet 6 inches in length, and 25 inches in circumference at the thickest part. A tusk dredged up at Dungeness is described by Professor Owen as measuring 11 feet in length. An imperfect molar of the same species (collected by the Author, and now in the British Museum) from the River Gravel near Kettering, Northamptonshire, weighed when found 14 lbs. Teeth, tusks, and bones of Elephants, representing more than 20 individuals of the species *antiquus* and *primigenius*, have been obtained from the gravels of the Nene Valley between Northampton and the Fens, a distance of about 45 miles.

‡ "The discovery of the carcase of the *Tichorhine Rhinoceros* in frozen soil, recorded by Pallas in his '*Voyages dans l'Asie Septentrionale*,' 1793, showed the same adaptation of this, at present tropical, form of quadruped to a cold climate, by a twofold covering of wool and hair, as was subsequently demonstrated to be the case with the Mammoth."—Professor Owen, *Palæontology*, p. 396.

Rhinoceros leptorhinus—a Fine-skinned Rhinoceros.
„ *hemitœchus*—a Slender Rhinoceros.
Hippopotamus major—Great Hippopotamus.
Cervus Megaceros—"Large-horned" (the great Irish Deer).
„ *Browni*—an Extinct Fallow Deer.
Bison priscus—Extinct Bison.
Bos primigenius—Ox of the first kind.
Equus spelœus—Cave Horse.
Rupi-capra Christolii—a kind of Chamois.
Lepus diluvianus—an Extinct Hare. And others.

b'. The following are still-existing species of *Mammalia* which in the same age inhabited, but are not now indigenous to, this country:—*Leopard*, *Lynx*, *Glutton*, *Arctic Fox*, *Wild Boar*, *Reindeer*, *Musk Buffalo*, *Grizzly Bear*, *Brown Bear*, *Wolf*, *Beaver*, *Horse*, the *Lagomys* or *Calling* or *Tailless Hare*, the *Ermine*, the Norwegian *Lemming*, the Greenland *Lemming*, and the *Spermophilus* (*Pouched Marmot*).

b''. During the same Period, there also lived on this area numerous animals of kinds still inhabiting Great Britain.

b'''. Contemporaneously with the animals named in the foregoing lists as having lived in this country and in Europe, others having entirely different characteristics flourished in South America; and it is remarkable that these consisted of animals allied to genera which exist now only in that region: such as—the *Mylodon* ("mill-tooth") and the *Megatherium* ("great beast"), colossal *Sloths* (a skeleton of the latter in the British Museum measuring 18 feet in length); and the *Glyptodon* ("sculptured tooth"), an *Armadillo* equally gigantic, of which an individual of a "smaller species" measures 9 feet in length and 7 feet across its dorsal armour following the curve.*

b''''. In like manner, fossil remains of *Maruspialia* (including immense forms of the *Kangaroo*, the head of one in

* Owen's *Palæontology*, p. 427.

the British Museum measuring three feet in length,) are found in Australia; where (and in Van Diemen's Land, New Guinea, and adjacent islands) living Marsupials alone occur.

55. The earliest indications of the presence of *Man* consist of *implements* or weapons made (by repeated chipping blows) of flint-stones. The *Post-Glacial* Period, accordingly, has been also called the "*Palæolithic Period*"*—Greek, "*palaios*," old, "*lithos*," stone; the oldest Stone Period.

The Palæolithic Period has been sub-divided into—

a. The more ancient—the *River Drift* or *Gravel Period*.

b. The less ancient—the *Cave Period*.

a'. In the older division of the Palæolithic deposits, the River Gravels, no human bones have with certainty been discovered, but only the rudest forms of chipped flint-implements and flakes. These are generally associated with the teeth and tusks of *Elephants*, the remains of *Rhinoceros*, *Hippopotamus*, *Bear*, *Cave Lion*, *Cave Hyæna*, great *Irish Deer*, *Reindeer*, *Bison*, great *Ox*, *Horse*, or some of them.

a''. In Gray's Inn Lane, London, 160 years ago, a fine flint-implement was dug up, and with it an Elephant's tooth. At Hoxne in Suffolk, at the close of the last century, several flint-implements were found; and in 1859, others at the same place. Since that date, many flint-implements have been discovered in the valley of the Ouse near Bedford, in the gravels of the rivers Lark and Little Ouse in Norfolk and Suffolk, in gravel at Fisherton near Salisbury, and near Reculvers, Kent, in several localities near Southampton and elsewhere in Hampshire, in Kent, Surrey, Middlesex, and in many other places.†

a'''. The chief localities on the Continent in which Palæo-

* Lubbock—*Pre-historic Times*, 1865, p. 2.

† Evans—*Ancient Stone Implements*, 1872.

lithic implements from the River Gravels have been found are the neighbourhoods of Abbeville and Amiens, in the valley of the river Somme, in France. Indeed, it was the inquiry, in 1858 and 1859, as to the implements found in the fluviatile deposits of these districts, that led to the determination of the true character of such implements, and of the Geological Period to which they belonged.* They have since then been found in Greece, Italy, Spain, Palestine, at the Cape of Good Hope, and in India.†

a''''. That these flint-implements are really the work of Men's hands is shown by the fact that, although some thousands of them have been collected, they present as to form only a few types or patterns. Moreover, many of them have been fashioned by alternate blows given on the one side and on the other side of each edge. They cannot, therefore, be the result of accidental fracture.

b'. Among the most important *Caves* in this country which have been found to contain the remains of Man associated with extinct animals, are—Kent's Cavern and Brixham Cave, near Torquay; Wookey Hole, in Somersetshire; and the Long Hole, Gower, Glamorganshire.

b''. The human works in these Caves consist of chipped flint-implements and flint flakes or knives, and various objects in Reindeer's horn and bone—including (from Kent's Cavern) harpoon heads notched or barbed sometimes on one side and in some instances on both sides (and very like harpoon heads of the Esquimaux of the present day), an awl, a pin, and a veritable needle with an eye. No human bones of trustworthy authenticity have been discovered.

* Professor Prestwich—*Philosophical Transactions*, Pt. ii., 1860, p. 277; Evans—*Archæologia*, vol. xxxviii., 1860.

† Evans—*Ancient Stone Implements*; and *Anniversary Address, Geol. Soc.*, 1875.

b'''. The most remarkable Caves on the Continent are those of Belgium and the South of France. In these have been found the skeletons of Men, and with them, unpolished flint-implements, articles of bone, Stag's horn, and ivory, and absolutely works of art—a representation of a Reindeer carved on its own horn, similar carvings of other animals in horn, a Reindeer carved in limestone, and incised drawings of various animals on horns and bones (including an excellent representation of a Reindeer, with what appears to be intended for a landscape, with herbage and water *), and of the *Elephas primigenius* on a fragment of its own tusk, showing its peculiarities of shape and the curved form of its tusks, and indicating the shaggy character of its hide.†

b''''. In 1872, a human skeleton was found in a cavern at Mentone, associated with chipped flint-implements and the remains of animals of species living in Palæolithic times,‡ and under conditions seemingly implying formal interment.

Remarks.—It can be proved that during the Palæolithic Period the area of the British Isles formed part of the Continent of Europe. At an earlier age (the Pre-Glacial), vast herds of Elephants of three species roamed over that area. By a great subsidence during the Glacial Period,§ the greater part of that area was sunk beneath the Ocean, while the remainder was covered with thick ice; so that all terrestrial animal life was either destroyed or driven away—no Elephants could possibly have remained. Two species, however, (*E. antiquus* and *E. primigenius*), which had lived

* *Reliquiæ Aquitanicæ* (Christy and Lartet, edited by Professor Rupert Jones), page 279, fig. 98.

† *Reliquiæ Aquitanicæ*, Plate xxviii; Boyd Dawkins—*Cave Hunting*, etc., page 346, fig. 20.

‡ Lyell's *Antiquity of Man*, 1873, p. 143; *Geol. Mag.*, 1872, pp. 272, 368.

§ See *ante*, Sec. 53, *b*, *b'*, *b''*, pp. 172, 173.

in older times, *re-appeared* in the Palæolithic Period, after that area had again become land. They could only have come *overland* from the Continent. By the same route, also in the same manner (*on foot*), and in the same Geological age, *Man* must have migrated to this country.* The Geological Formations on either side of the British Channel indicate also a former continuity.

There is little doubt that, during the same Period, Africa was united to Spain at the Straits of Gibraltar, and to Italy across the area of the narrow and shallow seas severally separating Tunis, Malta, Sicily, and Calabria; that animals migrated from Northern Africa to Southern Europe, and from Central Europe to Britain; and that, following geographical and climatical changes, certain species died out, while others receded Northwards. Professor Boyd Dawkins has suggested that the present tribes of Esquimaux are the representatives of Palæolithic Man, who also travelled Northwards during these changes.†

56. The RECENT Period.

In the earliest part of the Geological Period "Recent," is a junction of what perhaps strictly should be called the *latest Geological* age with the *earliest Archæological*‡ age, and a continuing-on of the great Geological sequence, through the border-land of "Pre-historic" ages, into Historic and Modern times.

a. During the earliest ages of the "Recent Period," the prominent use of flint or stone for weapons or implements continued; and Sir John Lubbock§ has therefore grouped

* Professor Ramsay—*Physical Geology*, p. 250.

† *Cave Hunting*, pp. 353-359.

‡ Greek, "*archaios*," ancient, "*logos*," a discourse.

§ *Pre-historic Times*, 1865, p. 2.

them as the *Neolithic** Period. But a very considerable lapse of time marked the *passage* of the Palæolithic into the Neolithic Period: of 48 species of *Mammalia* recognized as living in Britain during the older Period, only 31 lived on into the later; while, so nearly did the Mammalian fauna of the later time agree with that of this day, that of those 31 species only *six* are not now living in this country.†

a'. Numerous Cave deposits of somewhat altered character belong to the *Neolithic* Period; but the occasional use of caves for the purposes of human habitation was continued on into long subsequent times. The character of the skulls and other remains of *Man* found both in these deposits and in those of the earlier Cave Period, have furnished interesting data for the study of the physical and intellectual status of the remotely ancient representatives of our race.

a''. Chiefly in Denmark, but also in Scotland, in Devonshire, and in Cornwall, near the mouth of the Somme river in France, and in other places, occur, generally near a shore, mounds of shells (of no great thickness, but often covering very large areas), which evidently have been the refuse heaps‡ of unknown peoples, living in the Neolithic age. They fed chiefly upon the Mollusca of the rifled shells of which these heaps were the receptacles, and which mainly consisted of Oysters, Cockles, Mussels, and Periwinkles.§ A similar heap in the Island of Herm near Guernsey has been shown to be post-Roman in date.‖

a'''. Of this Period also, are remains found in Lakes in Switzerland and some other European countries, and in

* Greek, "*neos*," recent, "*lithos*," stone—the more recent Stone Age.

† Boyd Dawkins—*Trans. of Pre-historic Congress*, 1868, p. 278.

‡ In Danish, "*kjökken-möddings*," or kitchen heaps or "middings."

§ Lubbock's *Pre-historic Times*, p. 171.

‖ Evans—*Ancient Stone Implements*, p. 222.

Ireland; which indicate the erection upon piles, away from the mainland, of dwellings and groups of dwellings (in one instance comprising some 300 wooden huts), so isolated evidently for the sake of security. The sites of these settlements are now sub-aqueous mudbanks (studded with the stumps of piles). From these, have been obtained numerous objects of antiquity, showing that a rather advanced degree of civilization had ultimately been reached — different kinds of corn (evidencing agricultural cultivation), bones and teeth of such a character as to indicate the domestication of animals, and coarse woven fabrics. It is plain that the dates of these structures ranged into subsequent ages.*

a''''. In this Period, the use of *Flint* was greatly extended: in some districts, the surface is literally strewn with small and rude arrow and javelin heads, knives, skin-scrapers, saws, awls, etc., so that it has come to be called by some the "Surface Stone Period." By degrees, the manufacture improved, until some objects were wrought with such symmetry of form and such delicacy of chipping as to be beyond the reach of any known process of manipulation at the present time. Rubbing and grinding also were introduced, and such excellence was ultimately attained (especially in Denmark), that, for smoothness of surface and keenness of edge, the latest stone-hatchets are unsurpassable.

b. During the last-mentioned age, the use of metals such as Bronze or Iron was unknown: there came a time, however, when *Bronze* (not difficult of fusion) gradually, and doubtless from a small beginning, came into use for cutting-tools, and by slow degrees superseded Flint and Stone—not universally, however, but first in one place and then in

* See Lyell's *Antiquity of Man*, 1873, p. 18.

another; so that, in regard to time, the use of the two kinds of materials may be said to have overlapped. The Period during which Bronze was in use was of very long duration, and has been called the "*Bronze Age.*"

c. In due course, Bronze, in like manner, gave way to *Iron*, and the "*Iron Age*" was inaugurated. This age, commencing in Pre-historic times, has continued until now, linking the remote past with the present day; which, of a truth, is emphatically of the "*Iron Age.*"

d. Gold was in use for ornament in all but the earliest of these "Recent" ages, and probably for monetary purposes during the latest.

e. The classification of these Ages must not be regarded as of a strictly chronological character, but as evidencing only certain stages of civilization: it is probable that all three Ages—the Neolithic, the Bronze, and the Iron—may have existed in different parts, even of Europe, at one and the same time*; and in some regions of the world, the Stone Age has reached down to a very recent period indeed.

f. The *fauna* of the Neolithic Period and succeeding Pre-historic ages may be considered as identical with that of the present time, although some forms have disappeared. Even during the Historic Period, the great Struthious Bird of New Zealand, the *Moa*, has died out; within the last three centuries, the *Dodo* of the Mauritius has become extinct; and during the present century, the *Great Auk*, an occasional visitant of British shores, has been lost. It is not impossible that new species, to supply the defections of these and of the previous Post-Glacial ages, have been introduced; but of such a fact we know nothing, evidence upon the question being unattainable.

* Evans—*Ancient Stone Implements*, p. 2.

Tabular View of the Succession of Animal and Vegetable Life upon the Earth.

Life Periods.	Animal Kingdom.	Geological Systems.	Vegetable Kingdom.
Eozoic or Protozoic.	Dawn of Animal Life. Age of Protozoa.	Lower Laurentian. Upper Laurentian.	Dawn of Vegetable Life.
Paleozoic.	First Zoophyta, Annelida, Mollusca, Crustacea, and Echinodermata.	Lower Cambrian.	
	First Polyzoa, Crinoidea, Radiata (Star-fishes), Conchifera, and Cephalopoda. Trilobites and Brachiopods, plentiful.	Upper Cambrian.	Vegetable Life, not abundantly represented. Character uncertain, probably Marine, & consisting of Algæ (Sea-weeds).
	First (and Age of) Graptolites. First Corals, Gasteropoda, and Curved Cephalopoda. Trilobites and Brachiopods, plentiful. First Vertebrata (Heterocercal Fishes) and Eurypterida (Crustacea).	Lower Silurian. Upper Silurian.	
	First Insects. Corals, Heterocercal Fishes, and Eurypterida, numerous.	Devonian and Old Red Sandstone.	First Acrogens (Club-mosses, Equisetums, Ferns, &c.), and Coniferæ (Cone-bearing Plants, and Plants allied to Yews).
	Crinoids, Placoid Fishes, and Insects, abundant. First (and Age of) Amphibian Reptiles. First Terrestrial Mollusca and Lacertilia.	Carboniferous. Permian.	
Mesozoic.	First Homocercal Fishes, Dinosaurian Reptiles, and Marsupial Mammals. Dawn of Ammonites.	Triassic.	First Cycadaceæ and Palms, with some elements of the Modern Flora.
	First (and Age of) Belemnites and Ammonites. Age of Flying and other Saurians. Insects, plentiful.	Liassic.	Coniferæ and Cycadaceæ abundant.
	First Birds. Age of Marsupials. Large Aquatic, Terrestrial, and Flying Saurians, abundant. First Turtles.	Oolitic. Cretaceous.	Beginning of Age of Modern Flora.
Cainozoic.	Turtles, numerous. First Tapiroids, Carnivora, Insectivora, Cetacea, Struthious Birds, Serpents. Dawn of Ruminantia.	Eocene.	Age of Modern Flora.
	First Elephantidæ, Equidæ, and Cervidæ and other Ruminantia.	Miocene. Pliocene.	
	Elephants in their zenith. Dawn of Existing Fauna and of Human Life.	Post Pliocene.	
	Existing Fauna. Age of Man.	Recent.	

Note.—The words, "Dawn," "First," "Beginning," are intended to apply only *as according to present knowledge.*

CONCLUSION.

A CONTEMPLATION of the long, varied, and for the most part continuous, series of the Earth's physical changes, as demonstrated by *Stratigraphical* phenomena, will leave upon the mind the prominent impression of the bewildering, the incomprehensible, lapse of time necessarily involved. Years, and cycles of years, are all inadequate to express the vast sum of the eons of the past—as compared with which, the completed history of the greatest river, of the widest continent, or even the long period of Man's hitherto career, would be but as a passing thought, or as a short episode in Nature's epic.

And a review of the *Life-History* of the Earth will be equally significant and suggestive. Not only does that Life-History also necessitate a lapse of time of incalculable duration; but it exhibits, through all its Periods down to the Recent age, an ever-accelerating advance, by an infinity of variations and developments, in the multiplicity of Life-forms, and in the complexity and completeness of their organization.

In the all but formless *Eozoon*, we have the earliest known trace of animal life; and we follow on—to the perhaps doubtful *Oldhamia*—thence to minute Sponges, obscure Annelids, humble Mollusca, proto-Crustaceans—on, to more and more organized animal structures, to the variation and advancement of pre-existing forms, and to the introduction in ever-increasing numbers of newer types.

We trace the advent, the culmination, the decadence, and the disappearance, of whole families of genera; and we note their replacement by others of higher grade. We recognize a general, although irregular, advance—in animal organization, locomotive power, and perceptive or instinctive capacity; and we see how, when new classes of organisms appear, that these bear, as it were, lingering traces of affinity (either dormant or active) to other and older types. Thus—the earliest Fishes, in their armour-coating, bear a strong resemblance to preceding Crustaceans; the earliest Reptiles (*Archegosauri*) have affinity to Fishes; and Reptiles themselves foreshadow Bird-structure: the earliest Mammals, in the pelvic-pouch process of maturing their young, seem only partially to have advanced beyond the oviparous and incubationary process of Birds; the flying Reptile prefigures the flying Bat; the earliest fossil Bird, in its osseous structure, exhibits the Lacertian tail; and Birds only gradually and later on lose Reptilian traits.

Animal life appears to have advanced more rapidly in its latter stages; but occasional indications of linking affinities are still to be detected: Serpents have evolved from Lizards, Fishes and Mammals find alliance in the Whales; certain dental peculiarities connect with Mesozoic Marsupials Early Eocene Tapiroids; and these, through other Pachyderms, shade gradually into the Ruminants of somewhat later times. And, thus, a subtle sympathy (perhaps having an hereditary source) seems to bind all life in mysterious unity.

At length, *Man* appears upon the scene—and under conditions strange, and such as by which *he* alone could have been distinguished. The existence of every other Life-form has been made known only by its fossil frag-

ments—by its bodily self: but the *mind* of Man has yielded the earliest indications of his being; for, in Geological sequence, the first occurrence of his bodily remains is greatly preceded by that of his handiworks. Rude though they be, these exhibit the intellectual qualities of purpose, contrivance, and the adaptation of means to an end, widely separating their possessor from all other living entities; and the germs of intelligence and manipulatory power thus primarily displayed, through long-sustained and ever-increasing mental and physical culture, have developed into the science and civilization of the present time.

Geology—stratigraphical and palæontological—has thus taught us much of the great Physical and Life History of the Earth, brought down to the era of our own Race: but it leaves us here, with no certain initiation into the mysteries of the future—no penetration into the infinite unknown.

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